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GROUND WATER

IN

SOUTHWESTERN PENNSYLVANIA

By

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of the United States Geological Survey

With Analyses by Margaret D. Foster and C. S. Howard

(Prepared in cooperation between the United States Geological Survey and the Pennsylvania Topographic and Geologic Survey)

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CONTENTS

Page

Page

ILLUSTRATIONS

GROUND WATER IN SOUTHWESTERN PENNSYLVANIA

By Arthur M. Piper

INTRODUCTION

Scope of the investigation

The area treated in the present report covers about 4,700 square miles in the southwest corner of Pennsylvania and includes Butler, Allegheny, Washington, Westmoreland, Fayette, and Greene counties. (See fig. 1.) It includes the industrial area about Pittsburgh

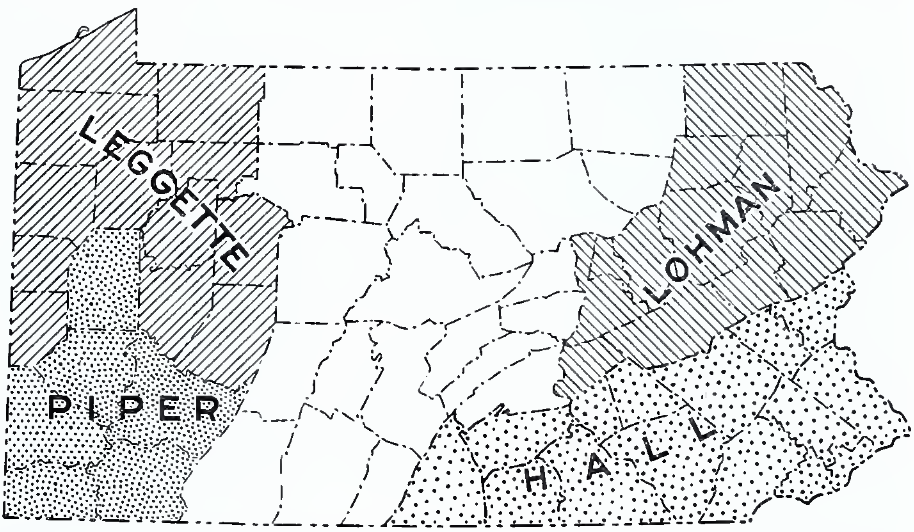

Figure 1.—Index map of Pennsylvania showing area covered by this report and progress of ground-water surveys.

and much of those parts of the State that yield petroleum, natural gas, and bituminous coal. (See fig. 2.)

The investigation that forms the basis of this report is a part of a survey of the ground-water resources of the State which is being made, in cooperation, by the Pennsylvania Topographic and Geologic Survey and the United States Geological Survey. The writer was assigned to the area in August, 1926, and remained in the field until the middle of November.

The entire area is covered by standard topographic maps of the United States Geological Survey and most of it is covered by detailed geologic folios. The investigation of ground water consisted largely in collecting well data, interpreting the occurrence, head, quantity, and quality of the water with respect to the rock formations and structure and studying the best methods of constructing wells and recovering the water. Samples of water were collected from 89 representative wells and springs in the area and, for the purpose of comparison, 3 samples were taken from surface streams. These waters were analyzed by Margaret D. Foster and C. S. Howard in the water resources laboratory of the United States Geological Survey. The work was done

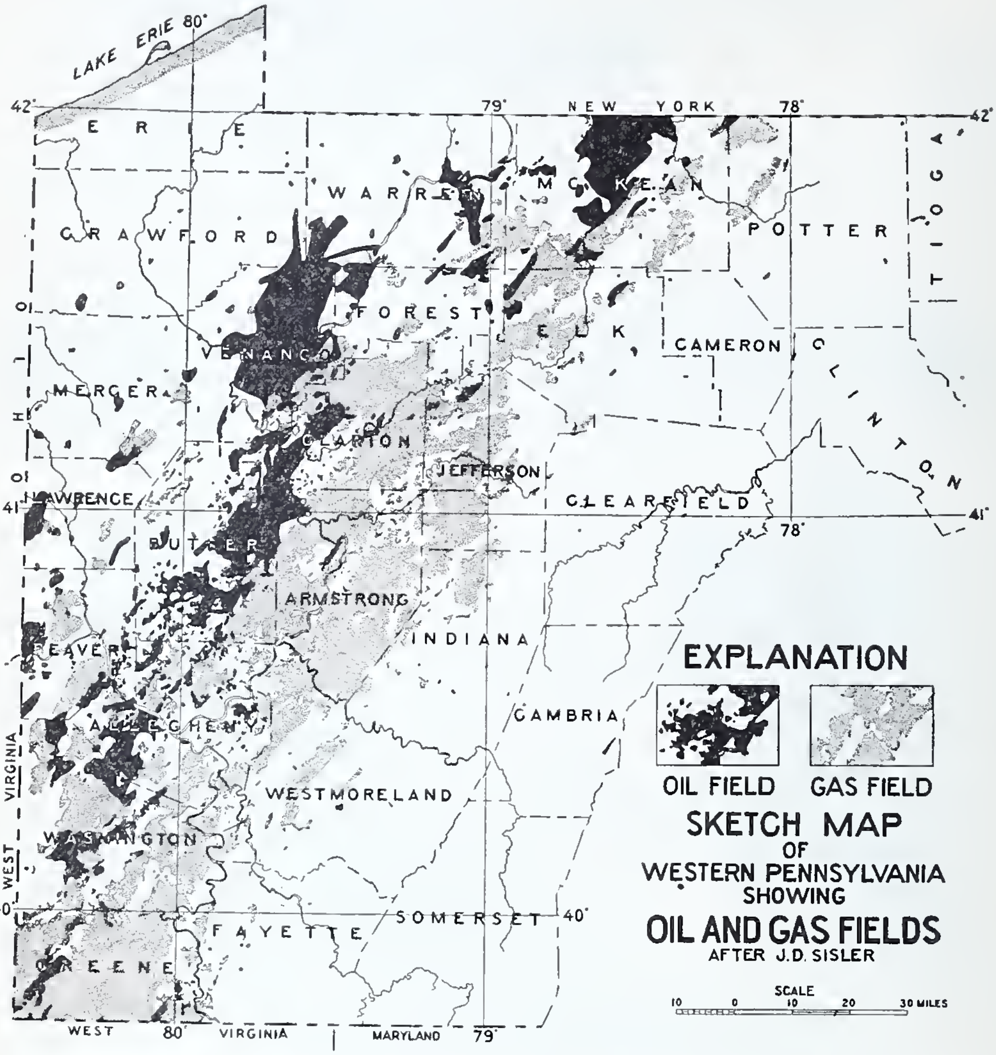

Figure 2.—Map of western Pennsylvania, showing the location of oil and gas fields.

under the technical supervision of O. E. Meinzer, geologist in charge of ground-water investigations of the United States Geological Survey, who has given the writer much constructive criticism.

Previous geologic investigations

Because of its classic Carboniferous section and its vast store of mineral resources, southwestern Pennsylvania has been the field of a great amount of geologic study. In 1836, under the direction of H. D. Rogers, the Commonwealth began a preliminary study of its stratigraphic problems in relation to coal resources. The investigation was abruptly suspended in 1841, was reopened in 1851, and was finished in 1858 with the publication of a general report.[1]

In 1874 the Second Geological Survey of Pennsylvania was formed

[1] Rogers, H. D., The geology of Pennsylvania, a government survey, 2 vols., 586 and 1046 pp., maps, Philadelphia, 1858.

under J. P. Lesley, who had been an assistant to Rogers in the work of 1836-1854. During Lesley's term the bituminous coal fields and petroliferous areas of the western part of the State were studied in moderate detail by Carll,[2] Chance,[3] d'Invilliers,[4] Franklin Platt,[5] Stevenson,[6] I. C. White,[7] and others. During the same period Lesquereux[8] continued his classic studies of the paleobotany of the coal measures, and Fontaine[9] classified the flora of the overlying Permian or Upper Barren measures. The field work of the Second Survey was brought to an end in 1889, and its activity terminated in 1895 with the publication of Lesley's final report.[10]

In 1899 the Legislature of Pennsylvania created a Topographic and Geologic Survey Commission whose purpose was to cooperate financially with the United States Geological Survey in the topographic and geologic mapping of the State. A detailed investigation of the bituminous basin by Federal geologists was begun by Campbell[11] and during subsequent years was extended into the petroliferous area by

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[2] Carll, J. F., Report of progress in the Venango oil district: Pennsylvania Second Geol. Survey, Rept. I, pp. 1-49, 1875; Oil well records and levels: Pennsylvania Second Geol. Survey, Rept. I-2, 398 pp., 1877; The geology of the oil regions of Warren, Venango, Clarion, and Butler counties: Pennsylvania Second Geol. Survey, Rept. I-3, 482 pp. and atlas, 1880; Geological report on Warren County and the neighboring oil regions, with additional oil well records: Pennsylvania Second Geol. Survey, Rept. I-4, 439 pp. 1883; Preliminary report on oil and gas: Pennsylvania Second Geol. Survey, Ann. Rept. for 1885, pp. 1-81, 1886; Report on the oil and gas regions: Pennsylvania Second Geol. Survey, Ann. Rept. for 1886, pt. 2, pp. 575-786, maps by C. A. Ashburner and E. V. d'Invilliers, 1887; Seventh report on the oil and gas fields of western Pennsylvania: Pennsylvania Second Geol. Survey, Rept. I-5, 356 pp., 1890.

[3] Chance, H. M., The northern townships of Butler County; a special survey along the Beaver and Shenango Rivers in Beaver, Lawrence, and Mercer counties: Pennsylvania, Second Geol. Survey, Rept. V, 248 pp., 1879.

[4] d'Invilliers, E. V., Preliminary report of work done in 1885 on the resurvey of the Pittsburgh coal region: Pennsylvania Second Geol. Survey, Ann. Rept. for 1885, pp. 125-221, 1886; Report on the Pittsburgh coal region: Pennsylvania Second Geol. Survey, Ann. Rept. for 1886, pt. 1, pp. 1-372, 1887.

[5] Platt, Franklin, Special report on the coke manufacture of the Youghiogheny River valley in Fayette and Westmoreland Counties, with geological notes of the coal and iron ore beds: Pennsylvania Second Geol. Survey, Rept. L, 252 pp., 1876.

[6] Stevenson, J. J., Report of progress in the Greene and Washington district of the bituminous coal fields of western Pennsylvania: Pennsylvania Second Geol. Survey, Rept. K, 419 pp., 1876; Report of progress in the Fayette and Westmoreland district of the bituminous coal fields of western Pennsylvania: Pennsylvania Second Geol. Survey, Rept. K-2, 437 pp., 1877; Report of progress in the Fayette and Westmoreland district of the bituminous coal fields of western Pennsylvania, Part II, The Ligonier Valley: Pennsylvania Second Geol. Survey, Rept. K-3, 331 pp. 1878.

[7] White, I. C., Report of progress in the Beaver River district of the bituminous coal fields of western Pennsylvania: Pennsylvania Second Geol. Survey, Rept. Q, 337 pp., 1878; The geology of Lawrence County, to which is appended a special report on the correlation of the Coal Measures in western Pennsylvania and eastern Ohio: Pennsylvania Second Geol. Survey, Rept. Q-2, 336 pp., 1879; The geology of Mercer County: Pennsylvania Second Geol. Survey, Rept. Q-3, 233 pp., 1880; The geology of Erie and Crawford counties: Pennsylvania Second Geol. Survey, Rept. Q-4, pp. 1-355, 1881.

[8] Lesquereux, Leo, General remarks on the distribution of the coal plants in Pennsylvania, and on the formation of the coal, in Rogers, H. D., Geology of Pennsylvania, vol. 2, pp. 837-847, 1858; Description of the fossil plants found in the anthracite and bituminous coal measures of Pennsylvania: Idem. pp. 847-884; Description of the coal flora of the Carboniferous formation in Pennsylvania and throughout the United States: Pennsylvania Second Geol. Survey, Rept. P, 977 pp. in 3 vols.; vols. 1, 2, 1880; vol. 3, 1884; atlas, 1879; On the character and distribution of Paleozoic plants: Pennsylvania Second Geol. Survey, Ann. Rept. for 1886, pt. 1, pp. 457-522, 1887.

[9] Fontaine, W. M., and White, I. C., The Permian or upper Carboniferous flora of West Virginia and southwestern Pennsylvania: Pennsylvania Second Geol. Survey, Rept. P-2, 143 pp, 1880.

[10] Lesley, J. P., A summary description of the geology of Pennsylvania [in part by E. V. d'Invilliers and others]: Pennsylvania Second Geol. Survey, Final Rept., 3 vols. and atlas, 2,588 pp., 1892-1895.

[11] Campbell, M. R., U. S. Geol. Survey Geol. Atlas, Masontown-Uniontown folio (No. 82), 21 pp., 1902; Brownsville-Connellsville folio (No. 94), 19 pp., 1903; Latrobe folio (No. 110), 15 pp., 1904.

Butts and Leverett,[12] Stone,[13] Woolsey,[14] Clapp,[15] Griswold,[16] Munn,[17] and Shaw[18]. The cooperative activity of the Commission continued until 1919, although greatly curtailed during the chaotic period of the World War.

In 1919 a newly created Bureau of Topographic and Geologic Survey with George H. Ashley as State Geologist assumed the functions of the preceding Commission and also instituted a program for the completion of the detailed geologic mapping of the State. Of the publications of this Bureau, those which apply to the area under discussion are a summary description of the bituminous coal fields by Sisler,[19] and treatises on the geology of the Greensburg and Pittsburgh quadrangles by Johnson[20].

In addition to the major publications to which reference has been made, the technical literature includes a vast number of shorter papers which bear upon the geology of southwestern Pennsylvania. Limitations of space preclude their complete tabulation at this place, although an effort has been made to acknowledge by suitable footnote reference each one that has contributed to the text of the present paper. Even in this great volume of literature, however, the references to the occurrence of ground water are extremely fragmentary and do not constitute an adequate treatment of the subject.

Acknowledgments

Adequate investigation of the problem would not have been possible unless the well drillers and residents throughout the area had contributed whole-heartedly and intelligently from their store of experience with ground-water conditions. Individual mention of all who have contributed in this manner is, however, impracticable. Neither has it been feasible to confer with all who were interested in the investigation. Material assistance was rendered by Mr. Reineke, of the Reineke-Wagner Pump & Supply Co., and by Mr. Long, of the Pittsburgh Pump & Supply Co., both of Pittsburgh, in bringing the writer

[12] Butts, Charles, and Leverett, Frank, U. S. Geol. Survey Geol. Atlas, Kittanning folio (No. 115), 15 pp., 1904. Butts, Charles, Economic geology of the Kittanning and Rural Valley quadrangles, Pennsylvania: U. S. Geol. Survey Bull. 279, 198 pp., 1906.

[13] Stone, R. W., U. S. Geol. Survey Geol. Atlas, Waynesburg folio (No. 121), 12 pp. 1905; Elders Ridge folio (No. 123), 10 pp., 1905; Stone, R. W., and Clapp, F. G., Oil and gas fields of Greene County: U. S. Geol. Survey Bull. 304, 110 pp., 1907.

[14] Woolsey, L. H., U. S. Geol. Survey Geol. Atlas, Beaver folio (No. 134), 16 pp., 1905; Economic geology of the Beaver quadrangle: U. S. Geol. Survey Bull. 286, 132 pp., 1906.

[15] Clapp, F. G., Limestone of southwestern Pennsylvania: U. S. Geol. Survey Bull. 249, 52 pp., 1905; U. S. Geol. Survey Geol. Atlas, Amity folio (No. 144), 15 pp., 1907; Rogersville folio (No. 146), 14 pp., 1907; Economic geology of the Amity quadrangle, eastern Washington County: U. S. Geol. Survey Bull. 300, 145 pp., 1907

[16] Griswold, W. T., and Munn, M. J., Geology of the oil and gas fields in Steubenville, Burgettstown, and Claysville quadrangles, Ohio, West Virginia, and Pennsylvania: U. S. Geol. Survey Bull. 318, 196 pp., 1907.

[17] Munn, M. J., Geology of the oil and gas fields of the Sewickley quadrangle, Pennsylvania: Pennsylvania Top. and Geol. Survey Rept. 1, 170 pp., 1910; U. S. Geol. Survey Geol. Atlas, Sewickley folio (No. 176), 16 pp., 1911; Oil and gas fields of the Carnegie quadrangle, Pa.: U. S. Geol. Survey Bull. 456, 99 pp., 1911; U. S. Geol. Survey Geol. Atlas, Claysville folio (No. 180), 14 pp., 1912.

[18] Shaw, E. W., and Munn, M. J., Coal, oil and gas of the Foxburg quadrangle, Pa.: U. S. Geol. Survey Bull. 454, 85 pp., 1911. Shaw, E. W., U. S. Geol. Survey Geol. Atlas, Burgettstown-Carnegie folio (No. 177), 16 pp., 1911. Shaw, E. W., Lines E. F., and Munn, M. J., U. S. Geol. Survey Geol. Atlas, Foxburg-Clarion folio (No. 178), 17 pp., 1911.

[19] Sisler, J. D., Bituminous coal fields of Pennsylvania; Part II, Detailed descriptions of coal fields: Pennsylvania Top. and Geol. Survey, 4th ser., Bull. M-6, pt. 2, 511 pp., 1926.

[20] Johnson, M. E.: Pennsylvania Top. and Geol. Survey, Top. and Geol. Atlas, Greensburg quadrangle (No. 37), 1926; Pittsburgh quadrangle (No. 27), 1929.

into contact with drilling contractors. The Bessemer & Lake Erie Railroad, through F. R. Layng, assistant chief engineer at Greenville, submitted descriptive data and analyses of the water supplies along its right of way. The Pittsburgh office of the Corps of Engineers, U. S. Army, contributed valuable information regarding gravel deposits of the Ohio River and its tributaries. Mr. H. C. Kneeland, of the Ohio Valley Water Co. at McKees Rocks, added a comprehensive manuscript report on the occurrence of ground water in these same deposits of gravel. The T. W. Phillips Gas & Oil Co., of Butler, and the Peoples Natural Gas Co., of Pittsburgh, through J. French Robinson, chief geologist, and James Henderson, W. D. Griffith, and J. L. Ridgway, field superintendents, gave freely from their files of well data and their experience with water conditions in deep wells.

CLIMATE

PRECIPITATION

The average annual precipitation in different parts of western Pennsylvania ranges between 34 and 50 inches. It is least in the lower Ohio and Beaver valleys and increases eastward with some regularity.

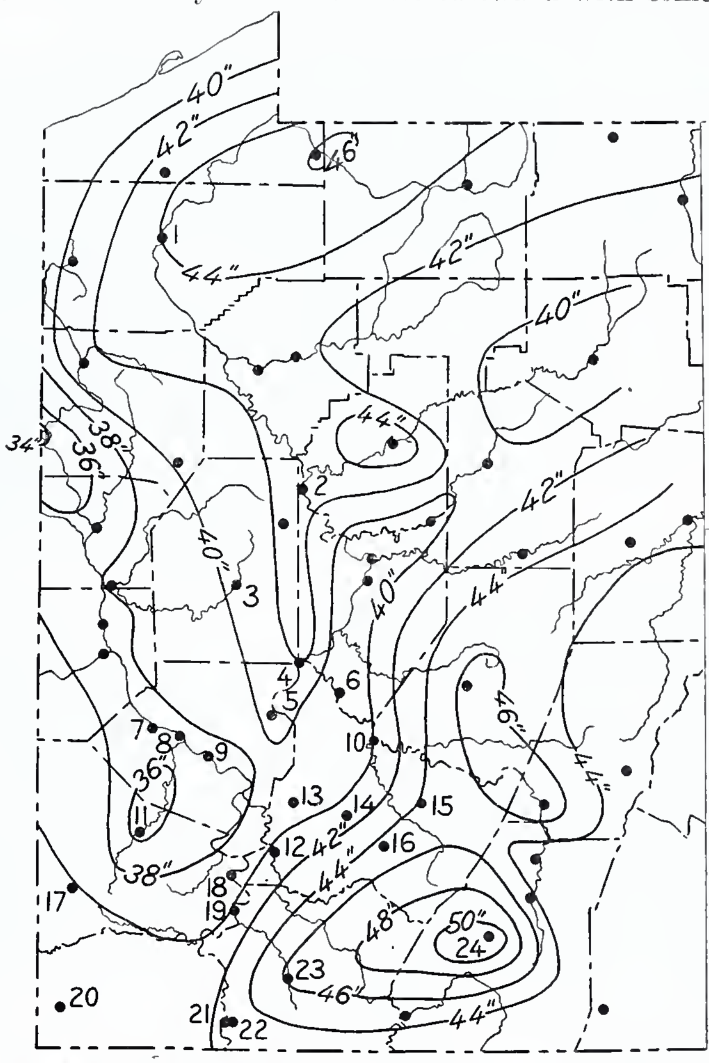

Figure 3.—Map of western Pennsylvania showing climatologic stations and distribution of precipitation.

(See fig. 3.) In general the amount of precipitation is related closely to the topography, the broad lowland valleys receiving a minimum of rain and snow and the uplands of the eastern portion of the area receiving a maximum. This relation does not apply in detail, however, especially to a single year's conditions.

Normal monthly and annual precipitation in inches at 25 stations in southwestern Pennsylvania.

(From records of U. S. Weather Bureau.)

No. on Fig. 3	Station	Altitude (feet above sea level)	Length of record (years)	January	February	March	April	May	June	July	August	September	October	November	December	Annual
1	Saegerstown[a]	1,120	32	3.37	3.03	3.40	3.34	4.45	4.35	4.25	4.13	3.55	3.60	3.28	3.26	44.01
2	Parkers Landing	900	39	3.41	3.08	3.58	3.56	3.82	4.34	4.34	4.17	3.30	2.88	2.85	3.18	42.51
3	Butler	1,000	11	3.00	2.27	3.24	3.12	3.36	5.01	4.02	4.81	2.87	3.23	2.62	2.66	40.21
4	Freeport	750	47	3.85	3.16	3.63	3.32	3.88	4.26	4.18	3.72	2.87	2.89	2.89	3.38	42.03
5	Springdale	820	19	3.68	2.52	3.41	3.28	3.56	4.26	3.79	4.31	3.19	3.32	2.03	3.17	40.52
6	Vandergrift	825	8	3.21	2.40	2.40	2.81	3.69	4.54	3.33	5.10	2.32	3.75	2.22	2.85	38.62
7	Coraopolis	720	19	3.31	2.50	3.22	3.14	3.05	3.70	2.76	3.29	2.64	2.97	1.77	2.80	36.15
8	Davis Island dam	720	30	3.01	2.67	3.31	3.05	3.29	4.10	4.02	3.31	2.51	2.37	2.13	2.86	36.63
9	Pittsburgh	842	81	2.87	2.66	3.01	2.90	3.30	3.89	3.42	3.18	2.48	2.36	2.55	2.73	36.35
10	Saltsburg	850	29	3.78	2.99	3.19	3.33	3.42	4.02	3.95	3.90	3.33	3.17	2.10	3.30	40.48
11	Canonsburg	936	19	3.18	2.30	3.02	2.82	3.29	3.41	4.14	3.03	3.60	2.60	2.54	2.61	35.71
12	West Newton	800	36	3.49	3.06	3.63	3.32	3.56	4.15	4.49	3.95	2.60	2.69	2.32	3.29	40.55
13	Irwin	884	28	3.04	2.25	3.54	3.35	3.24	4.65	4.16	4.07	2.77	2.83	2.26	2.95	39.11
14	Greensburg	1,150	18	3.75	2.86	2.80	3.65	3.73	4.10	3.79	4.37	3.20	3.13	1.96	3.15	40.49
15	Derry	1.172	29	3.91	2.99	4.06	3.72	3.45	4.85	4.83	4.17	2.81	3.25	2.57	3.30	43.91
16	Lycippus	1,420	34	4.07	3.04	3.74	3.78	3.96	4.49	5.04	4.31	3.03	3.05	2.56	3.69	44.76
17	Claysville	1,127	22	3.53	2.49	3.32	3.49	3.44	4.15	4.32	4.33	2.80	3.32	1.94	2.95	40.08
18	Lock No. 4	735	41	3.19	2.73	3.30	3.17	3.67	4.01	4.35	3.62	2.78	2.76	2.40	2.89	38.87
19	California	770	6	3.20	2.26	3.92	3.12	2.89	4.46	4.79	3.60	2.19	2.37	1.90	2.93	37.63
20	Aleppo	1,135	16	3.86	2.63	3.66	3.50	3.80	4.10	4.84	3.49	2.80	2.88	2.07	3.26	40.89
21	Greensboro	850	32	3.44	2.97	3.62	3.38	3.88	4.83	4.82	3.52	2.97	2.92	2.90	3.10	42.35
22	New Geneva	940	9	4.30	3.12	3.33	2.61	3.26	4.36	4.49	4.11	2.92	2.65	2.61	3.02	40.78
23	Uniontown	999	38	3.85	3.13	3.96	3.75	4.07	4.91	5.06	4.83	3.18	3.21	3.11	3.60	46.66
24	Somerset[b]	2,280	44	4.76	3.98	4.34	4.64	5.02	5.14	4.44	4.72	3.67	3.12	3.46	3.95	51.24
--	Baldwin[c]	1,404	6	4.19	2.83	3.37	3.36	3.30	4.08	3.72	4.03	3.81	3.66	2.13	3.40	41.88

[a] In Crawford County, northwestern Pennsylvania.
[b] In Somerset County, southwestern Pennsylvania.
[c] Record fragmentary. Station not numbered on Figure 3.

The normal precipitation in western Pennsylvania varies somewhat from month to month, the greatest precipitation occurring in June in the northern part of the area and in July in the southern part. The least monthly precipitation at most of the Weather Bureau stations, however, occurs in November, though at some stations it occurs in February, September, or October. At Pittsburgh the greatest precipitation occurs in July, which has a mean of 3.89 inches, and the least in October, which has a mean of only 2.36 inches. The largest amount of precipitation in one month at this station, whose record covers 81 years of the period 1837 to 1926, was 9.51 inches, in July, 1887, and the least 0.06 inch, in October, 1874. Figure 4 shows these relations more fully.

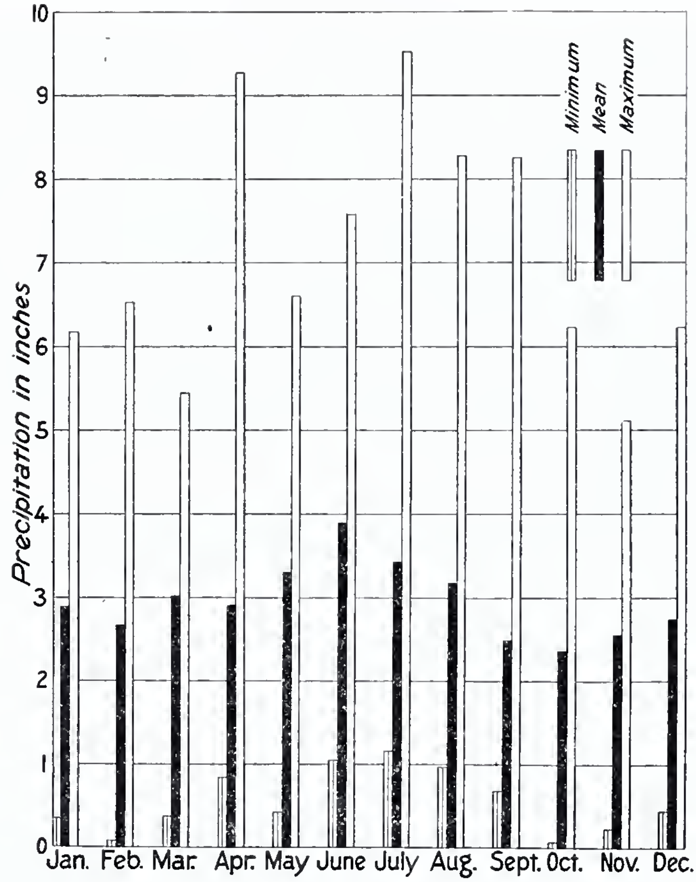

Figure 4.—Minimum, mean, and maximum monthly precipitation at Pittsburgh for the period 1837-1926.

The annual precipitation at Pittsburgh for the 81 years of record is shown by the accompanying table and by Figure 5. From 1837 to 1867 observations were made at the old Allegheny Arsenal, in

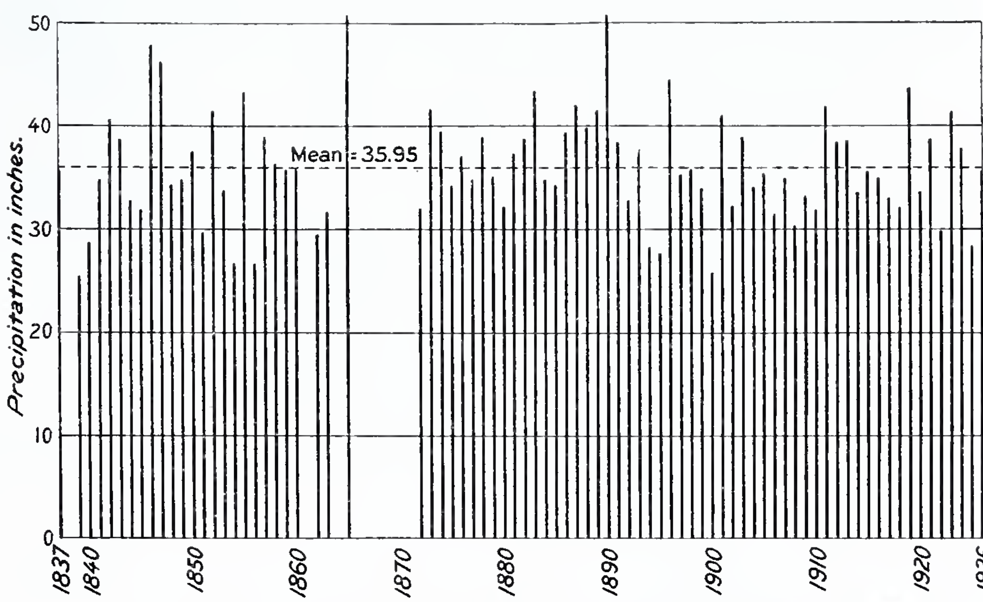

Figure 5.—Annual precipitation at Pittsburgh during the period 1837-1926.

the eastern edge of Pittsburgh, and after 1872 at or near the site of the present station, in the downtown business district. As the average annual precipitation is 35.68 inches according to the earlier record and 36.07 inches according to the later record, the two periods may justly be regarded as comparable portions of a single record. For the entire period the average was 35.95 inches; the greatest was 50.61 inches, in 1890; and the least was 25.32 inches, in 1839. The longest period of more than normal precipitation was the six years 1886 to 1891, for which the average was 41.89 inches. The longest period of less than normal precipitation was the seven years 1904 to 1910, for which the average was 32.89 inches. The following tables reveal variations of a similar order of magnitude at each of 20 stations in the area, though none of the records are as long as that for Pittsburgh.

Precipitation in inches by years prior to 1885.

4. Freeport													
1878	36.63	1879	39.25	1880	44.68	1881	42.69	1882	45.10	1883	------	1884	43.61
9. Pittsburgh													
1837[a]	35.66	1844	32.55	1851	29.64	1858	36.18	1865	50.50	1872	31.91	1879	37.02
1838	------	1845	31.89	1852	41.36	1859	35.71	1866	------	1873	41.42	1880	31.97
1839	25.32	1846	47.79	1853	33.63	1860	35.78	1867	------	1874	39.42	1881	37.30
1840	28.64	1847	46.22	1854	26.67	1861	------	1868	------	1875	34.05	1882	38.63
1841	34.85	1848	34.14	1855	43.33	1862	29.38	1869	------	1876	37.01	1883	43.17
1842	40.45	1849	34.81	1856	26.59	1863	31.62	1870	------	1877	34.72	1884	34.82
1843	38.71	1850	37.41	1857	38.96	1864	------	1871	------	1878	38.76		
11. Canonsburg													
1856	24.70	1859	40.28	1862	------	1865	43.92	1868	35.55	1871	29.31	1874	40.85
1857	40.85	1860	------	1863	32.00	1866	39.86	1869	37.96	1872	26.75	1875	34.28
1858	34.87	1861	37.34	1864	41.88	1867	28.93	1870	35.39	1873	40.37	1876	33.32
24. Somerset													
1840	33.39	1841	32.35	1846	44.52	1858	37.35	1859	36.86	1860	49.32	1861	40.07

[a] Record for the period 1836–1867 made at Allegheny Arsenal.

(From records of U. S. Weather Bureau. Extremes prior to 1921 only.)

Annual precipitation in inches, at 20 stations in southwestern Pennsylvania.
(from records of U. S. Weather Bureau. Numbers which accompany station names refer to corresponding number on Figure 3.)

	1	2	4	5	7	8	9	10	12	13	14	15	16	17	18	20	21	23	24
Calendar year	Saegerstown	Parkers Landing	Freeport	Springdale	Coraopolis	Davis Island dam	Pittsburgh	Saltsburg	West Newton	Irwin	Greensburg	Derry	Lycippus	Claysville	Lock No. 4	Aleppo	Greensboro	Uniontown	Somerset
1885		48.09	43.80				34.12												
1886		32.52	46.02				39.21								39.75				
1887		33.25	34.41				41.95								39.19				
1888							39.89								47.29			52.10	47.80
1889		39.53	44.21				41.37	43.73							45.10		46.68	54.56	51.34
1890		57.29	57.93				50.61	58.28							62.75		65.15	70.68	66.26
1891		45.24	42.39			40.25	38.28	43.53	39.31						45.40		49.14	51.12	50.13
1892	51.42	41.62	35.07				32.66	35.31	32.93						33.75		36.17	44.68	41.25
1893	49.60	51.50	43.55			36.71	37.84	35.00	37.93				41.87		36.96		33.76	38.99	45.00
1894	**31.97**	**43.84**	**32.18**			**29.69**	**28.17**	**35.47**	31.73				41.43		32.16		35.74	41.43	57.15
1895	37.95	35.57	30.83			26.04	27.50		29.57				31.85		24.88		34.64	38.65	31.48
1896	41.48	40.33	42.51			41.33	44.35		48.29				46.80		45.33		46.71	49.46	52.61
1897	52.20	43.33	46.31			38.22	35.08		37.52	38.13		43.10	42.83		33.22		40.47	45.08	47.80
1898	50.64	46.93	46.32			38.47	35.76		43.54	41.89		45.67	48.64		42.39		48.63	50.72	55.19
1899	37.53	39.41	39.64			38.42	33.85		39.79	38.41		44.73	41.47		38.65		49.90	50.74	51.13
1900	41.00	38.41	37.88			29.24	25.73		34.79	30.96		40.95	39.36		31.01		44.53	47.34	55.68
1901	48.89	50.55	53.73			44.80	40.76		41.42	37.73			45.87		41.32	37.23	44.34	52.78	55.44
1902	45.94	40.88	40.94			33.89	32.22	37.00	42.10	40.89		49.09	42.04		36.83	46.00	41.81	47.86	56.39
1903	48.63	47.60	42.10			**33.44**	**38.81**		**44.96**			42.38	37.57		40.68	44.22	42.19	38.05	45.20
1904	46.88	41.86	41.70			38.35	33.76	40.62	36.36	41.05		39.10	37.97		33.40	34.69	34.14	31.94	50.44
1905	42.32	45.86	44.01			37.45	35.19		48.23	47.66		51.19	51.51	42.49	42.44	39.56	45.49	46.21	59.38
1906	44.94	40.18	43.51	42.70		36.83	31.29	36.20	37.90	42.47		39.76	44.41	35.18	37.30	38.93	36.64	42.65	56.70
1907	48.92	42.30	42.75	**43.16**		38.21	34.86	44.26	44.83	49.62		50.21	49.69	48.33	43.56	54.53	50.89	54.60	64.05
1908	38.78	41.08	43.12	37.83	32.82	32.99	30.17	38.60	35.37	35.45		41.73	38.60	41.60	33.78	35.87	36.54	38.75	49.87
1909	42.23	43.96	39.49	36.80	33.77	31.30	33.18	42.26	40.69	35.72	37.04	36.86	39.84	35.45	40.21	37.65	34.56	43.04	41.76
1910	43.83	38.96	41.52	35.77	31.42	32.25	31.80	38.46	37.06	31.41	36.08	34.55	45.00	37.10	33.57	35.58	36.32	39.50	47.04
1911	45.26	53.22	48.56	50.07	43.23	47.69	41.29	46.41	44.77	44.30	43.83	45.40	52.16	**46.64**	43.68	**44.07**	44.63	54.51	**63.99**
1912	40.58	44.55	42.91	**43.48**	35.00	**37.01**	38.30	**42.21**	**50.80**	44.39	49.75	51.20	54.32	42.23	41.72	38.03	46.71	48.68	60.95
1913	48.67	41.42	41.62	42.74	39.63	40.43	38.49	38.46	45.02		45.89	46.58	53.03	42.89	36.99	42.59	**47.23**	**54.92**	**49.67**
1914	40.94	39.22	38.33	37.65	36.53	37.80	33.48	35.76	36.95	34.20	36.58	39.05	44.39	38.85	31.98	39.37	35.66	40.76	54.33
1915	46.37	36.71	39.53	39.69	38.09	39.38	35.50	38.39	41.74	36.82	37.05	40.77	44.68	40.75	34.60		40.05		59.61
1916	41.87		39.16	37.47	33.88	35.37	34.86	41.79	45.10	35.17	41.00	46.71	48.79	40.34	37.12	44.24	41.88	46.78	55.73
1917	44.92		43.92	37.39	33.51	34.03	32.90	37.23	37.14	33.95	39.38	40.03	47.21	39.76	32.29	41.46	39.45	37.34	55.20
1918	40.18	44.92	41.15	36.86	33.53	42.17	32.15	35.99	44.52	39.02	43.90	42.91	47.98	35.83	38.25		41.00	41.16	53.99
1919		39.51	45.65		42.05	46.37	43.49	45.15	47.54	44.07	43.75	48.34	57.12	42.83	43.69		44.15	52.05	57.05
1920		42.87	37.90		32.96	35.46	33.67	40.91	39.81	35.30	40.97	42.84	43.92	34.38	39.31		36.80	47.20	57.70
1921		41.33	44.89		46.18	43.16	38.57	50.50	44.85	44.67	49.13	49.64	54.71	47.13	43.14			55.44	62.91
1922		30.16	37.17	39.38	30.65		29.84	35.99	34.81	34.11	36.26	36.78	38.78	33.13	31.27			35.56	42.94
1923	39.16	38.42	46.93	46.66	40.38		41.52	48.55	35.87	39.26	44.66	46.43	46.99	40.94	36.25			42.31	51.85
1924	42.61	40.67	46.16	42.26	41.90		37.70	48.15	36.07	33.94	44.14	49.86	46.72	45.31	37.33			42.74	55.80
1925	38.21	36.65	35.78	36.32	35.38		28.19	40.06	34.67	27.44	37.55	42.32	44.07	38.31	35.36			40.17	
1926		46.38	50.36	44.32			35.44	40.23	39.22	34.11	42.23	45.37	49.02		40.74			45.91	
Average[b]	43.80	42.21	42.30	40.59	36.72	37.39	35.95	41.49	40.09	38.29	41.62	43.92	45.31	40.45	38.65	40.88	42.25	46.22	50.53

[a] Record for the period 1836-1867 made at Allegheny Arsenal.
[b] Computed for all tabulated data.

Greatest 24-hour rainfall, in inches, at six stations in southwestern Pennsylvania.

(From records of U. S. Weather Bureau. Extremes prior to 1921 only.)

No. on Fig. 3	Station	Length of record (years)	January	February	March	April	May	June	July	August	September	October	November	December	Annual
1	Saegerstown	25	1.60	3.50	3.70	1.83	2.59	3.10	5.66	3.47	2.54	1.71	1.45	1.40	5.66
9	Pittsburgh	49	2.34	2.01	2.04	3.60	2.96	3.19	3.85	3.65	4.08	1.91	1.85	2.44	4.08
17	Claysville	17	1.50	1.43	2.00	1.40	2.13	3.15	2.15	2.15	1.85	2.00	2.42	1.60	3.15
20	Aleppo	17	2.20	1.08	2.40	2.03	2.35	1.74	2.45	2.08	2.25	1.90	1.75	2.66	2.66
23	Uniontown	25	1.82	1.92	2.40	1.82	1.97	2.72	2.93	3.03	2.03	1.80	1.80	2.63	3.03
24	Somerset	25	2.10	1.85	2.70	3.15	2.30	2.65	2.50	4.45	3.25	1.76	3.00	2.10	4.45

Heavy downpours lasting a few hours may occur at any season of the year but are most severe during the summer. The greatest recorded rainfall during 24 hours within the area was 5.66 inches, at Saegerstown, and falls of 2 to 3½ inches in a 24-hour interval are not uncommon at any station.

TEMPERATURE

The mean annual temperature is from 50.2° to 52.6° F. at the stations in the area; it is less farther north and on the upland to the east, being 47.1° at Saegerstown and 47.5° at Somerset. The highest mean monthly temperature occurs in July and ranges between 72° and 75° at the several climatologic stations; the lowest occurs in January or February and ranges from 28° to 31°. The highest temperature recorded in the area is 108°, for July, at Claysville; and the lowest is —29° for January, at Derry; but at Somerset, on the upland to the east, the minimum is even lower, being —35°. For western Pennsylvania as a whole, therefore, the maximum recorded range in temperature is 143°, although for the individual stations it ranges between 123° F. and 134°. The annual range in temperature at any one station is generally less than 105°.

Average mean monthly and annual temperature, in degrees Fahrenheit, at 13 stations in southwestern Pennsylvania.

(From records of U. S. Weather Bureau. Averages including 1920.)

No. on Fig. 3	Station	Length of record (years)	January	February	March	April	May	June	July	August	September	October	November	December	Annual
1	Saegerstown	28	25.0	23.1	34.5	45.3	56.9	64.7	69.0	67.3	61.4	50.3	38.6	28.7	47.1
6	Vandergrift	7	30.0	30.3	39.6	50.7	61.2	69.0	73.3	72.0	64.2	56.0	42.4	31.9	51.7
9	Pittsburgh	49	31.0	31.3	39.6	50.9	62.5	70.6	74.7	72.7	66.4	54.9	42.7	33.8	52.6
11	Canonsburg	22	29.0	31.9	38.1	50.0	60.0	68.9	72.0	69.8	63.3	51.7	40.7	32.6	50.7
13	Irwin	19	30.9	29.0	40.9	50.4	61.6	69.0	72.4	71.2	64.4	54.7	42.7	32.3	51.6
14	Greensburg	12	30.6	30.0	38.8	41.4	60.5	67.1	71.9	70.7	64.2	53.8	42.2	31.6	50.2
15	Derry	22	30.4	28.1	40.1	49.3	61.5	68.6	73.3	71.3	65.4	54.4	41.9	31.7	51.3
16	Lycippus	26	29.6	27.8	39.3	49.4	61.0	67.9	72.4	71.0	65.6	54.1	42.0	31.9	51.0
17	Claysville	15	30.9	29.8	40.6	50.6	61.3	68.2	72.7	71.5	65.2	53.7	41.5	31.9	51.5
19	California	12	32.7	29.3	43.7	50.6	61.8	68.4	73.3	71.7	67.1	55.3	42.9	34.7	52.6
20	Aleppo	17	30.4	29.3	41.3	49.9	61.1	67.1	72.0	70.3	64.8	53.4	41.3	31.2	51.0
23	Uniontown	30	32.2	31.3	40.8	50.9	62.2	69.9	73.1	71.9	63.7	54.5	43.3	34.7	52.2
24	Somerset	52	26.4	26.5	35.5	46.2	57.1	65.3	68.7	67.2	60.7	49.0	38.5	28.6	47.5

The data given above form the basis of Figure 6, which brings out both local and seasonal variations.

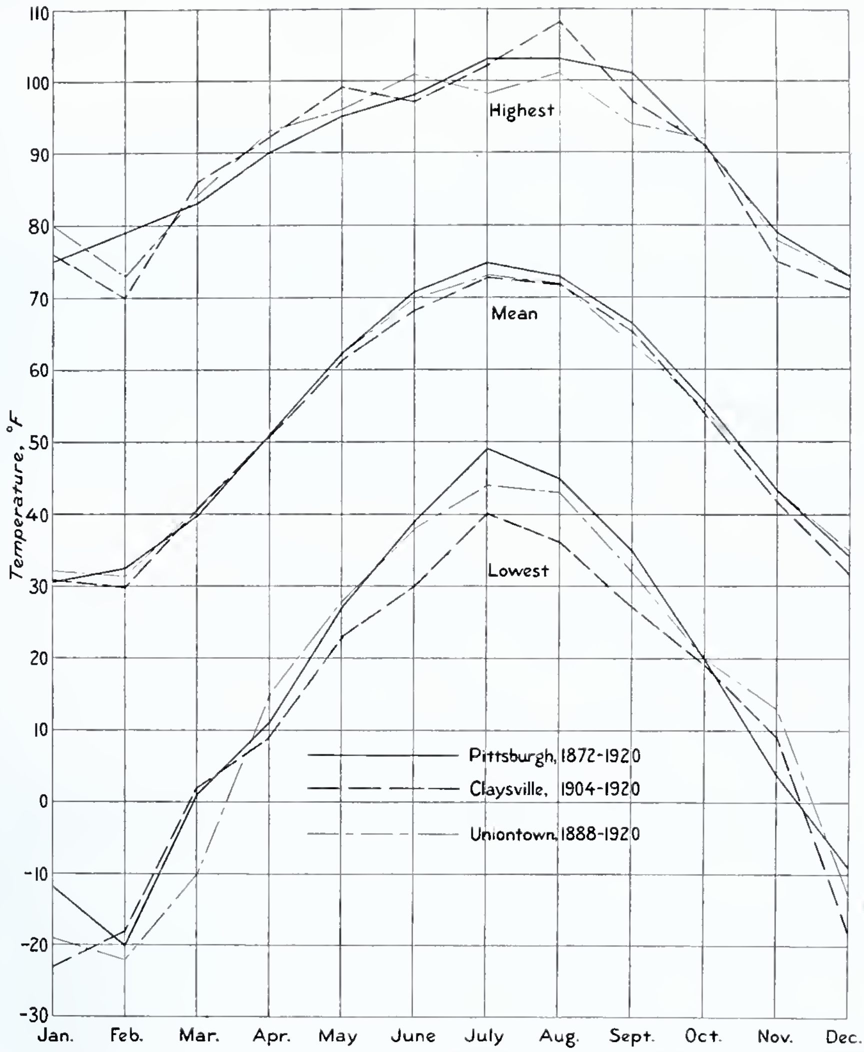

Figure 6.—Variations of monthly temperature at stations in southwestern Pennsylvania.

The frost-free period is moderately long in the six counties examined, the average being from 143 to 178 days at the several stations. The adjoining stations at Saegerstown and Somerset, however, have average frost-free periods of only 128 and 134 days respectively.

Frost data for stations in southwestern Pennsylvania.
(From records of U. S. Weather Bureau.)

No. on Fig. 3	Station	Length of record (years)	Latest killing frost in spring		First killing frost in autumn		Frost-free period (days)		
			Average date	Latest date	Average date	Earliest date	Shortest recorded	Average	Longest recorded
1	Saegerstown	33	May 22	June 17	Sept. 27	Sept. 10	85	128	163
9	Pittsburgh	54	April 22	May 29	Oct. 21	Sept. 25	131	178	215
13	Irwin	22	May 6	May 27	Oct. 6	Sept. 11	132	151	203
15	Derry	30	May 11	June 10	Oct. 3	Sept. 11	105	146	176
16	Lycippus	33	April 28	May 27	Oct. 18	Sept. 10	132	173	208
17	Claysville	23	May 13	June 10	Oct. 4	Sept. 11	96	143	177
20	Aleppo	19	May 11	May 28	Oct. 2	Sept. 11	108	143	171
23	Uniontown	32	April 26	May 28	Oct. 17	Sept. 19	141	174	212
24	Somerset	33	May 18	June 17	Sept. 29	Sept. 11	86	134	171

SURFACE FEATURES

PHYSIOGRAPHIC DISTRICTS

Southwestern Pennsylvania lies wholly within the physiographic province known as the Appalachian Plateaus. For purposes of detailed description, however, the area is divisible into two districts by a line that follows the western flank of Chestnut Ridge and passes about 3 miles east of Uniontown in Fayette County and thence trends about N.30°E. through Connellsville and just east of Derry in Westmoreland County (Pl. 1). To the west of this line lies an extensive mature plateau of moderate relief and fine texture, which forms a part of the Kanawha section of the Appalachian Plateaus. To the east is a mature upland plateau of strong relief, which constitutes the Allegheny Mountains section.

KANAWHA SECTION

The Kanawha section, within the area covered by this report, consists in most places of rounded hills and ridges, products of the submature dissection of a once featureless plain whose character is suggested by the few flat summit areas. In the northern part the tributary drainageways are broad valleys of rounded contour from 200 to 300 feet deep. The master streams and the lower courses of the largest tributaries, however, have been entrenched to greater depth during several stages of erosion and present a relief of about 500 feet. From the latitude of Washington northward to and beyond Pittsburgh the interstream crests, or upland remnants, reach altitudes between 1,200 and 1,250 feet above sea level and mark a slightly undulating surface which is approximately horizontal in its broad aspects. Northward these crest altitudes rise gradually to 1,550 feet in northern Butler County. Campbell[21] has shown that this is but part of an extensive deformed erosion surface which attains a maximum altitude of 2,100 feet in McKean and Potter counties, in the north-central part of the State, and thence slopes radially toward the south. This erosion surface, originally termed the Harrisburg peneplain, is now believed to be above the peneplain typically developed near that city at about

[21] Campbell, M. R., Geographic development of northern Pennsylvania and southern New York: Geol. Soc. America Bull., vol. 14, pp. 277-296, 1903.

520 feet above sea level. It has lately been called the Allegheny peneplain by the State Geologist, from its fine development throughout the drainage basin of Allegheny River. The characteristic topography of this surface is well viewed from vantage points along the ridge south of Little Connoquenessing Creek, about 27 miles north of Pittsburgh. (Fig. 7).

Figure 7. Typical topography of the submaturely dissected Allegheny peneplain. Looking northwestward into valley of Little Connoquenessing Creek from a vantage point 1½ miles west of Connoquenessing Borough.

Figure 8. Deeply-dissected topography in Greene County. View on Dyers Fork north of Kirby.

Southward and westward from Washington to the corner of the State, on the other hand, the ridges become sharp and locally uneven in altitude, although they increase progressively in elevation and attain a maximum of about 1,600 feet in Greene County. The country is also more deeply dissected and less maturely rounded, a relief of 500 to 650 feet being common even in headwater localities.

ALLEGHENY MOUNTAINS SECTION

In southwestern Pennsylvania the Allegheny Mountain section of the Appalachian Plateaus is bounded on the west by Chestnut Ridge,

a bold strike ridge which rises as much as 1,500 feet above the Allegheny peneplain. It trends N.30°E. entirely across the area covered by this report and parallel to its eastern edge, a distance of 60 miles, in which it is pierced by only three streams. Its somewhat uneven crest attains a maximum altitude of 2,778 feet above sea level in southern Fayette County and declines gradually northward. To the east of Chestnut Ridge and parallel to it at a distance of about 9 miles is a second outstanding ridge, Laurel Hill, whose crest ranges from 2,800 to 3,000 feet above sea level. The crest of Laurel Hill forms the eastern boundary of the area covered by this report. The belt between these two dominating ridges is an intricately dissected submature terrain whose summits range from 1,500 to 2,300 feet above sea level and whose relief ranges from 500 to 1,200 feet.

DRAINAGE SYSTEM

The entire area covered by this report is tributary to the Mississippi River system, Ohio River being the immediate master stream. The principal drainageways of the region are shown on the geologic map (Pl. I). Ohio River is formed by the junction at Pittsburgh of the Allegheny and Monongahela rivers, whose far-flung tributaries rise in New York, Pennsylvania, Maryland, and West Virginia and drain an area of about 18,000 square miles.

Allegheny River enters the area from the north, touches the extreme northeast corner of Butler County, swerves eastward and southward, touchs the southeast corner of the county opposite Freeport, and thence flows southwestward to Pittsburgh. At Freeport the Allegheny is joined from the southeast by Kiskiminetas River, which is in turn formed by the junction of Conemaugh River and Loyalhanna Creek at Saltsburg. These streams drain a portion of the Allegheny Mountain region in Westmoreland County, as well as a contiguous area in Armstrong, Indiana, Cambria, and Somerset counties. Kiskiminetas and Conemaugh rivers form the northern boundary of Westmoreland County.

Monongahela River rises in north-central West Virginia, enters Pennsylvania south of Point Marion, and thence follows a meandering course northward between Greene and Washington counties on the west and Fayette and Westmoreland counties on the east. Its chief tributary, Youghiogheny River, rises in the mountainous part of West Virginia, flows northwestward across the Allegheny Mountain region of Westmoreland County, then northward parallel to Monongahela River for some 20 miles, and joins that stream about 10 miles south of Pittsburgh. Other tributaries of the Monongahela are Tenmile and Pigeon creeks from Washington County on the west and Cheat River and Redstone Creek from Fayette County on the east.

Ohio River flows northwestward from Pittsburgh about 25 miles, leaving this area at Leetsdale, Allegheny County. At Beaver it is joined from the north by Beaver River, which receives the drainage from the greater part of Butler County through Connoquenessing and Muddy creeks. Chartiers Creek, another notable tributary of the Ohio, drains large portions of southwestern Allegheny County and northern Washington County.

On the easily eroded rocks of the Kanawha section the streams follow courses independent of the geologic structure and have reduced their

beds to gentle slopes, the Ohio, Allegheny, and Monongahela rivers, for example, having gradients of only 1 to 1½ feet to the mile within the area surveyed. In the Allegheny Mountain section, however, only the three major streams—Conemaugh River, Loyalhanna Creek, and Youghiogheny River, named in order from north to south—have been able to cut valleys athwart the folded Pottsville and Pocono sandstones, but none has yet cut its bed to grade. For example, Conemaugh River slopes about 11 feet to the mile between Johnstown, Cambria County, and Saltsburg as it pierces the folded sandstone strata of the Allegheny Mountains, whereas its northward extension, Kiskiminetas River, has a gradient of about 3 feet to the mile between its mouth and the junction of Loyalhanna Creek as it crosses the Kanawha section. The tributaries of Conemaugh River, Loyalhanna Creek, and Youghiogheny River are subsequent streams which have developed strike valleys parallel to the anticlinal ridges.

GEOLOGIC AND PHYSIOGRAPHIC HISTORY[22]

Although the oldest rocks exposed in southwestern Pennsylvania are of early Carboniferous age, the drill has reached Silurian strata in the search for natural gas or petroleum, and other portions of the State expose a full sequence of strata down to the pre-Cambrian crystalline rocks. From these stratigraphic sections it is possible to reconstruct the geologic history of the area, the early chapters being outlined sketchily and the later chapters, which bear upon ground-water conditions, being given in some detail.

Pre-Cambrian rocks, which are among the oldest known to geologic science, constitute the basement upon which the thousands of feet of sedimentary rocks that occupy the Appalachian region were deposited during the Paleozoic era. These sedimentary rocks were formed of waste from the land masses that bordered the interior Paleozoic seas. Deposition was not continuous, however, and the conditions of sedimentation were not stable. At times the land masses stood relatively high, and their steeply graded streams bore coarse materials which formed extensive strata of conglomerate and sandstone. At other times the lands were lower, as a result either of long-continued erosion or of subsidence, and the streams became sluggish and carried only the finer land waste, which was deposited over wide areas and by consolidation formed shale. At times limestone was deposited perhaps far from shore or when the land masses were relatively very low and the streams were unable to transport a load of sediment. The texture of many beds, widely spaced in the thick mass of accumulated sediments, shows that they were deposited in shallow water or subaerially along a coastal plain, so that there was undoubted progressive subsidence of the region throughout the epoch of sedimentation. The character of other strata points to a stable sea bottom during relatively long periods and that of still others to a fluctuating strandline, so that periods of crustal oscillation must have alternated with periods of crustal stability, even though the net movement was steadily downward.

Concurrently with the sedimentation, organisms of various types

[22] This section is adopted in large part from Butts, Charles: U. S. Geol. Survey Geol. Atlas, Kittanning folio (No. 115), pp. 10-12, 1904.

were evolved. Their remains, entombed by contemporaneous sediments, are the fossils by which the age of the strata may be determined and by which separated sections of the rocks may be correlated with one another. The first organisms were simple marine animals and the lower forms of marine plants, but subsequently land plants made their appearance and evolved into the luxuriant species which eventually produced the many coal beds of the Appalachian province. These organic forms show that most of the early Paleozoic sediments are of marine origin and that the latest Paleozoic sediments are wholly of fresh-water or subaerial origin. They show further that the environment of sedimentation alternated between marine and fresh-water conditions for long periods.

PALEOZOIC TIME PRIOR TO THE UPPER DEVONIAN

During the Cambrian period sedimentation proceeded almost continuously in the Appalachian geosyncline in central and south-central Pennsylvania. The Lower Cambrian is represented by about 3,750 to 5,000 feet of sandstone and shale overlain by 1,800 feet or less of dolomite. During the Middle Cambrian the sea receded notably in the northern part of the trough, although in south-central Pennsylvania sandstone, shale, and limestone with a maximum thickness of 1,750 feet were deposited. In Upper Cambrian time the sea again advanced, and 2,000 to 3,000 feet of shaly limestone and calcareous shale were deposited.

During Lower Ordovician* and much of Middle Ordovician time the land masses remained low, there was not much erosion, and a great thickness of limestone and dolomite accumulated. In the Middle Ordovician epoch, a broad crustal uplift produced the Cincinnati geanticline along an axis which trended somewhat west of south through Cincinnati, Ohio, and Nashville, Tenn. Along this axis the earth's crust was periodically reelevated and persisted through middle and late Paleozoic time as a low ridge or island chain which hemmed in the Appalachian province on the west. Crustal disturbance was general near the end of the Middle Ordovician epoch, with the result that erosion was accelerated and fine sediments, which are now shale, were interleaved with beds of limestone, the proportion of argillaceous sediments increasing steadily until the end of the epoch. Between 5,200 and 9,000 feet of sediments were accumulated in south-central Pennsylvania during the Ordovician period (including the Canadian of the State Survey).

An interval of erosion followed the Ordovician sedimentation, and then the area was again inundated by marine waters and a great volume of sandy sediments, with a maximum thickness of about 2,000 feet, was deposited during the early part of the Silurian period. In middle and upper Silurian time the sediments were dominantly shaly throughout central Pennsylvania and New York, although conditions of sedimentation varied greatly in the Appalachian trough. That local desiccation of the shallow sea occurred in the early part of the upper Silurian epoch is attested by beds of salt encountered at a depth of 6,700 feet in the R. A. Geary well, near McDonald, Washington County.

* All of what is here called Lower Ordovician, in accordance with the practice of the United States Geological Survey, is classed as Canadian System by the Pennsylvania Geologic Survey. (See Pa. Geol. Surv. Bull. G. 1.)

At the end of the Silurian period there was apparently no general crustal disturbance in the Appalachian trough, and the deposition of calcareous sediments continued through earliest Devonian or Helderbergian time. However, the Lower Devonian epoch ended with the deposition of the persistent Oriskany sandstone. The total thickness of the sediments of middle and upper Silurian and Lower Devonian age (dominantly calcareous at the top) in south-central Pennsylvania is 2,200 feet.[23] In Middle Devonian time the sea transgressed widely and, after a maximum of 250 feet of Onondaga limestone had been deposited, some 1,250 to 2,500 feet of fine sediments, the Marcellus and Hamilton shales, were accumulated in central Pennsylvania. Conditions of sedimentation varied widely, somewhat sandy shale being prevalent in the eastern part of the region and limy shale, limestone, and dark-colored shale increasing in proportion toward the west.

The Marcellus and Hamilton shales were the first of a series of detrital mud and sand deposits tens of thousands of feet thick, the accumulation of which was to continue until the end of the Devonian period. Barrell[24] has interpreted this series as a vast delta comprising a piedmont gravel plain at the western flank of the Appalachian land mass, a subaerial plain of fresh-water and brackish-water sediments west of it, and a zone of shallow marine sediments still farther west.

UPPER DEVONIAN EPOCH

TULLY, GENESEE, AND PORTAGE DEPOSITION

Upper Devonian time was marked by a great spreading of shallow seas and the confluence of the Appalachian sea with waters from the Arctic Ocean. Locally sedimentation began with the deposition of the Tully limestone, which is not more than 5 feet thick if present in Pennsylvania, but over most of the area the Genesee shale, which is typically a dark carbonaceous bed of fine texture, was the first to be deposited. This formation was followed by the detrital Portage, which in western Pennsylvania is a series of flaggy argillite and local interleaved sandstone and limestone members. Toward the south and east the Portage grades into sandy shale and uniform-grained sandstone.

CHEMUNG DEPOSITION

The deposition of the Portage formation was followed by that of the Chemung, which in areas adjacent to southwestern Pennsylvania is composed of alternating thin beds of light-gray, green, and chocolate-colored shale, sandstone, and impure shell limestone, the shale predominating. The texture and succession of beds indicate an origin in a comparatively shallow water body which was receiving sediments from the adjacent lands—now fine, now coarse; at one time in abundance, at another more sparsely. The kind of material and rate of sedimentation varied rapidly and hence produced repeated alternations of strata. From time to time a quantity of coarse detritus would be brought in and assorted by wave or current action, forming a bed of coarse sandstone or conglomerate of moderate extent. At some times

[23] Butts, Chas., Geologic section of Blair and Huntingdon counties, Central Pennsylvania: Am. Jour. Sci. vol. 46, p. 536, 1918.

[24] Barrell, Joseph. The Upper Devonian delta of the Appalachian geosyncline; Am. Jour. Sci., 4th ser., vol. 36, pp. 429-472, 1913; vol. 37, pp. 87-109. 225-253, 1914.

organic forms were abundant and their shells accumulated with a small amount of fine sediment to form beds of impure limestone, but at other times the sand and mud were deposited so rapidly as to kill the organisms. The detrital beds of the Chemung formation in Pennsylvania range from 350 to 3,900 feet in thickness. As neither the beginning nor the end of this interval was marked by a distinct break in sedimentation, the strict time equivalence of the beds in separated localities is not assured.

CATSKILL DEPOSITION

Throughout the greater portion of New York and Pennsylvania the light-gray, green, and chocolate-colored beds of the Chemung are in part interbedded with and in part overlain by non-marine red beds which constitute the Catskill formation, of Upper Devonian age. These red beds, which range in thickness from 500 to 7,500 feet, represent the subaerial delta plain of Barrell. It has been known for many years that these highly-colored rocks do not represent a distinct time interval but rather were the product of sedimentation which persisted in the eastern near-shore zone of the Appalachian Gulf during post-Hamilton time and migrated westward with the advance of the Upper Devonian delta. Thus it results that the earliest Catskill beds, the Onconta sandstone of eastern New York, were deposited in the more or less landlocked northeastern extremity of the Appalachian Gulf at the same time that the early marine Portage was accumulating farther to the south and west. As time went on the Catskill sediment spread farther and farther westward, being contemporaneous at first with the Portage, later with the Chemung, and at the top probably with the lowest Mississippian beds. Toward the end of this epoch of red-bed deposition the finer sediments extended into western New York and Pennsylvania, where they at present constitute beds of soft red shale of irregular thickness and extent, which are interbedded with green and gray shale and sandstone bearing Chemung fossils and a few Carboniferous species. These extensive beds of coarse gray sandstone, form the chief reservoirs for oil and gas in southwestern Pennsylvania.

MISSISSIPPIAN PERIOD

POCONO DEPOSITION

The Mississippian period began with the deposition of the Pocono formation under conditions which did not differ notably from those of the preceding Upper Devonian epoch except that the rocks were prevailingly gray instead of red. In southwestern Pennsylvania the first strata deposited were dominantly sandy. These were followed by gray shale with a few beds of red shale of local extent and sporadic lenses of sandstone. During the later part of Pocono time vast quantities of sand were brought into the Appalachian Gulf and spread widely over the sea bottom, forming the coarse, massive, and relatively persistent Burgoon sandstone (Mountain or Big Injun sand).

The oldest rocks that crop out within the area covered by this report are of early or middle Pocono age.

LOYALHANNA DEPOSITION

At the end of Pocono time the Appalachian seas retreated from the northern part of the basin. Sedimentation was continuous farther

to the southwest in the Mississippi Valley, however, and the succeeding deposits constitute a transgressive group which extended eastward into western Pennsylvania. The first bed deposited in that area was the Loyalhanna limestone, an extremely cross-bedded nonfossiliferous member of Ste. Genevieve age, made up of well-rounded quartz grains and a subordinate amount of calcium carbonate, of which a small portion is oolitic. Butts[25] concludes that the Loyalhanna was formed by wind action on a low coastal plain, the calcareous matter being precipitated in the bordering sea, thrown up into bars and beaches by the waves, and thence blown landward and mingled by wind action with a plentiful supply of quartz grains.

MAUCH CHUNK DEPOSITION

The Loyalhanna formation was succeeded in places by about 50 feet of red shale, then by the highly fossiliferous Greenbrier limestone and then by more red shale, the conditions of sedimentation varying greatly. The Greenbrier member is of marine origin and was deposited only in a narrow seaway which entered southwestern Pennsylvania from the south. The red shale, on the other hand, represents a small part of a thick series of strata which Barrell[26] has suggested were probably deposited under semi arid conditions on a subaerial delta plain.

POST-MAUCH CHUNK EROSION

From its maximum thickness of more than 3,000 feet in northeastern Pennsylvania the Mauch Chunk formation thins westward and southward and on the Allegheny Front west of Altoona is but 180 feet thick. Still farther southwest, in Greene County, the formation is 270 feet thick, but to the northwest, in Armstrong, Butler, and Beaver counties, it is entirely absent. These relations are in part due to the transgressive nature of the formation. They are also due to erosion, which followed widespread uplift of northwestern Pennsylvania and adjacent areas and removed all of the Mauch Chunk formation and the upper part of the Pocono formation over extensive areas in the western part of the State.

PENNSYLVANIAN PERIOD

POTTSVILLE DEPOSITION

After the post-Mauch Chunk uplift of northwestern Pennsylvania and probably while the Mauch Chunk was being stripped from that area, the sea again advanced toward western Pennsylvania during Pottsville time. It was not until near the end of the Pottsville epoch, however, that sedimentation was resumed in the western part of the State, and the Sharon conglomerate and Sharon shale were deposited in Mercer County and contiguous areas. Over most of the area covered by this report, however, the Sharon beds were not deposited, and the succeeding Connoquenessing sandstone was laid down upon the eroded surface of the Mauch Chunk formation or of the Burgoon

[25] Butts, Charles, The Loyalhanna limestone of southwestern Pennsylvania, especially with regard to its age and correlation: Am. Jour. Sci., 5th ser., vol. 8, pp. 249-257, 1924.

[26] Barrell, Joseph, Origin and significance of the Mauch Chunk shale: Geol. Soc. America Bull., vol. 18, pp. 449-476, 1907.

sandstone at the top of the Pocono formation. The Connoquenessing sandstone comprises coarse sandstone and pebbly conglomerate, most of the grains of which are quartz. The coarse detritus of the Connoquenessing was succeeded over most of the area by the finer materials of the Mercer shale member, consisting of shale, limestone, clay, and coal. The Mercer sedimentation was followed by another influx of coarse land waste which formed the Homewood sandstone, the last deposit of Pottsville age in western Pennsylvania. Like the Connoquenessing, the Homewood sandstone is made up largely of grains and pebbles of quartz.

ALLEGHENY DEPOSITION

During Allegheny time, which succeeded the Pottsville, the conditions of sedimentation and consequently the character and thickness of the strata varied greatly from place to place, but the most outstanding feature was the formation of many beds of coal. Allegheny time began with the deposition of 10 to 30 feet of clayey sediment, and upon this was accumulated locally the vegetable matter which, by subsequent compaction and carbonation, formed the Brookville coal. The succeeding sediments ranged by lateral variation from fine silt to the sand that now forms the Clarion sandstone. Subsequently coal-forming conditions were restored, and the Lower Clarion and Upper Clarion coal beds, with intervening beds of shale, were deposited. This period of coal formation was followed by a rather general advance of marine waters, in which the Vanport limestone was deposited. The absence of detrital land waste in this limestone suggests that deposition took place at some distance from shore. Subsequent cycles of marine and possibly subaerial sedimentation, crustal oscillation, and coal-forming conditions caused the accumulation in turn of the Kittanning and Freeport groups, with their coals, under clays, and beds of sandstone, shale, and limestone.

CONEMAUGH DEPOSITION

The variable conditions of sedimentation that prevailed in Allegheny time continued into the succeeding Conemaugh stage, during which between 500 and 900 feet of strata were deposited. The major portion of these sediments consisted of silt, which is now compacted into shale, although many of the beds passed by lateral gradation into thick deposits of coarse sand from which the Mahoning, Saltsburg, Morgantown, and Connellsville sandstones were formed. Locally these sandy beds made up almost the entire column of Conemaugh sediments; elsewhere they were almost entirely absent. Conditions of sedimentation were even more variable, however, than is indicated by the complex stratigraphy of the silt and sand. Coal-forming conditions existed over certain areas at many times during the epoch, although on the whole they were much less prevalent than during the preceding Allegheny epoch. Local incursions of salt water are attested by the sporadic occurrence of marine fossils in the roof shale above the Upper Freeport coal, in discontinuous beds of dark limestone 100 to 150 feet above that coal, and in the highly fossiliferous Ames ("Crinoidal") limestone, which was deposited rather generally in western Pennsylvania and eastern Ohio near the middle of the Conemaugh epoch and

marks the latest demonstrable advance of marine waters into the area. At least the greater part of subsequent sedimentation during the Carboniferous period took place in fresh or brackish water or under subaerial conditions on a delta plain.

MONONGAHELA DEPOSITION

The Monongahela epoch succeeded the Conemaugh after slight local erosion and began with the formation of the Pittsburgh coal, by far the most widespread coal bed of the area here described. Coal-forming conditions were effective at this time over a vast area and were of long duration, as is attested by the thickness and persistence of this bed in the quadrant to the south and west of Pittsburgh and in a few detached areas as far east as Somerset County. The Pittsburgh coal was succeded by highly variable beds of silt and sand which were accompanied by an ever increasing proportion of calcareous matter, much of the later half of the epoch being represented by the thick Benwood limestone, the upper part of which is called Uniontown limestone. These limestones presumably were formed in fresh water. Coal-forming conditions recurred throughout the epoch and resulted in the successive formation of the Redstone, Sewickley, Uniontown, and Waynesburg coal beds. The Waynesburg coal marked the end of Monongahela deposition.

PERMIAN PERIOD

WASHINGTON DEPOSITION

During Permian time the variable conditions of the late Pennsylvanian continued, with a progressive decrease in both the frequency and the duration of the intervals during which coal and limestone were formed. In southwestern Pennsylvania the period began with the accumulation in places of the Cassville shale from a feather edge to 15 feet thick, which was followed by the deposition of course sand, now known as the Waynesburg sandstone. This coarse detritus was relatively widespread, although in many places a part or all of it graded laterally into fine silt or even into impure limestone. Subsequently coal-forming conditions returned locally, and the Waynesburg "A" coal bed was formed.

This bed was in turn succeeded by repeated alternations of shale, sandstone, fresh-water limestone, and discontinuous beds of coal, each bed being lenticular and passing into a different type by lateral gradation, at some places abruptly. This earliest epoch of the Permian terminated with the deposition of the Upper Washington limestone, the last persistent and heavy bed of limestone in the area.

GREENE DEPOSITION

The sediments of the Greene formation followed those of the Washington without a stratigraphic break, but the proportion of silt became greater and greater in the later part of the epoch. The intervals during which carbonaceous and calcareous sediments were formed were relatively sporadic and short, although both types of sedimentation were recurrent. Like those of the preceding epochs, the detrital sediments of the Greene epoch grade laterally from one type to

another, in many places abruptly. With the Greene epoch the traceable sedimentary record in this area comes to an end.

IGNEOUS ACTIVITY

At some time between the Permian and Pleistocene epochs the Carboniferous sediments were intruded by basic igneous dikes at two localities in western Pennsylvania. These intrusions are possibly a marginal phase of the intense igneous activity that occurred during the Triassic period in eastern Pennsylvania.

APPALACHIAN UPLIFT

With the cessation of sedimentation at the end of the Permian epoch the intermittent but progressive subsidence which had continued since early geologic time in the Appalachian trough came to an end. From that time until the present the region has been periodically elevated and has remained a land mass. The regional elevation was begun by an epoch of mountain making, during which the sedimentary rocks were deformed by gentle undulatory folds in the region of the present Kanawha section and by broad parallel northeastward-trending anticlines and synclines in the Allegheny Mountains section. This orogenic disturbance was by far the most pronounced event of the traceable geologic history of the region.

PRE-PLEISTOCENE PHYSIOGRAPHIC DEVELOPMENT

SCHOOLEY PENEPLAIN

The newly uplifted land mass was attacked by erosion and, after a long period of crustal stability, was planed down to a surface which is known as the Schooley peneplain, from its well-preserved remnants in the Schooley Mountains of New Jersey. No extensive remnants of this topographic feature are known to exist within the area covered by this report, although the nearly level crests of Chestnut Ridge and Laurel Hill, in eastern Fayette County, may not be far below its projected position.

ALLEGHENY PENEPLAIN

After the area had been thus worn down it was again elevated and dissected. The area underlain by the soft Permian and upper Pennsylvania rocks in southwestern Pennsylvania was reduced to a plain fully 1,500 feet below the Schooley peneplain, and the resulting lowland is known as the Allegheny peneplain (first described by Campbell as the Harrisburg peneplain). The resistant Pottsville and Pocono sandstones, however, formed prominent strike ridges, which now dominate the Allegheny Mountain section.

WORTHINGTON PENEPLAIN

The Allegheny peneplain was deformed and uplifted, presumably in Tertiary time, so that its remnants now reach an altitude of 2,100 feet in southwestern New York and of about 1,250 feet in the region about Pittsburgh. This crustal disturbance rejuvenated the streams,

and a new lowland, called by Butts[27] the Worthington peneplain, was formed about 150 feet below the Harrisburg peneplain in this area. Planation was not extensive, however, and the surface has been largely destroyed by subsequent erosion. In the type district near Worthington, in Armstrong County, it is marked by terrace remnants at an altitude of about 1,250 feet, and in the vicinity of Pittsburgh scattered remnants occur at 1,120 to 1,160 feet on the slopes of the larger valleys.

PARKER STRATH

The Worthington erosion cycle was terminated either by further crustal uplift or by increased run-off, which accelerated erosion, and the major streams of the region cut deep and broad meandering valleys below the Worthington peneplain. The ancestral Allegheny River, for example, eroded a valley floor as much as 1¼ miles wide and of very low gradient. To the assemblage of these broad valley floors the name Parker strath has been given, from the settlement of Parkers Landing, in northern Armstrong County, near which remnants of this topographic feature are well preserved. The strath (a wide valley with flat transverse profile) is now represented by broad rock shelves at a number of points on both slopes of the largest valleys, especially those of the Allegheny and upper Ohio rivers. In many places the shelves are veneered with younger glacial débris, but the term Parker strath is applied only to the rock surface of the ancient valley floor. These shelves occur about 200 feet above present water level, being at an altitude of 1,020 to 1,040 feet at Parkers Landing, 920 feet at Pittsburgh, and 900 feet at Beaver. Striking examples are the rock terraces on which are situated the communities of East Liberty, Homewood, Wilkinsburg, and Oakland, in the suburbs of Pittsburgh, as well as the boroughs of Avalon, Bellevue, and Coraopolis (in part), along the Ohio River, and of Birdville, in eastern Allegheny County. To the south, on Monongahela River, other remnants of the strath underlie the residential portions of Clairton and Bellevernon and the communities of Carmichaels and Masontown. The approximate position of the Parker strath with relation to the present streamways in the vicinity of Carmichaels and Masontown is well shown in Figure 9.

Leverett[28] believes that the Parker strath was developed approximately at the present level of its preserved remnants, whereas Butts[29] has concluded that these broad valleys were, at the time of erosion, considerably less than 1,000 feet above sea level and that the region has subsequently been elevated to its present position. The formation of the Parker strath probably occurred near the end of Tertiary time, for its further development was arrested by the Pleistocene glaciation.

During the erosion of the Parker strath the stream pattern of western Pennsylvania differed notably from that of the present day (see fig. 10) in that the drainage went northward into the present St. Law-

[27] Butts, Charles, op. cit., (Kittanning folio), p. 11.

[28] Leverett, Frank, Glacial formation and drainage features of the Erie and Ohio basins: U. S. Geol. Survey Mon. 41, pp. 147-148, 1902.

[29] Butts, Charles, op. cit., p. 11.

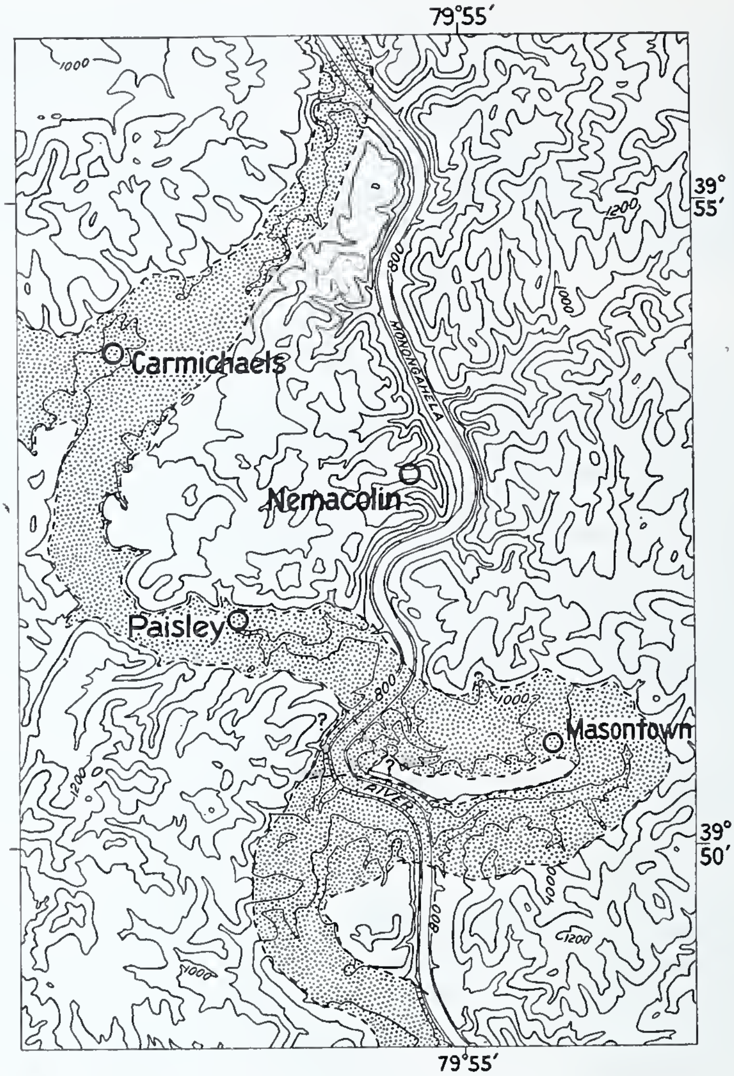

Figure 9. Map of the vicinity of Carmichaels and Masontown, showing relation of the Parker strath of pre-Pleistocene time to the present streamways.

rence Basin rather than westward and southward into the Mississippi Valley. The dominant stream rose on the highland of McKean County and, with minor deviations only, followed the course of the present Clarion River southwestward. Thence it occupied the lower Allegheny River and the present Ohio River as far as Beaver, flowed northward along the Beaver River (in the opposite direction to the present flow of that stream),[30] and followed the Grand River to its mouth. This master stream received an extensive tributary drainage from the south through the Youghiogheny, Monongahela, and Ohio rivers, the Ohio flowing northward from a preglacial divide in the vicinity of New Martinsville. The land about Tidioute and Meadville and the area along the Pennsylvana-New York boundary line were likewise drained northward by streams, which Leverett has designated Old Middle

[30] Hice, R. R., Northward flow of ancient Beaver River: Geol. Soc. America Bull., vol. 14, pp. 297-304, 1903.

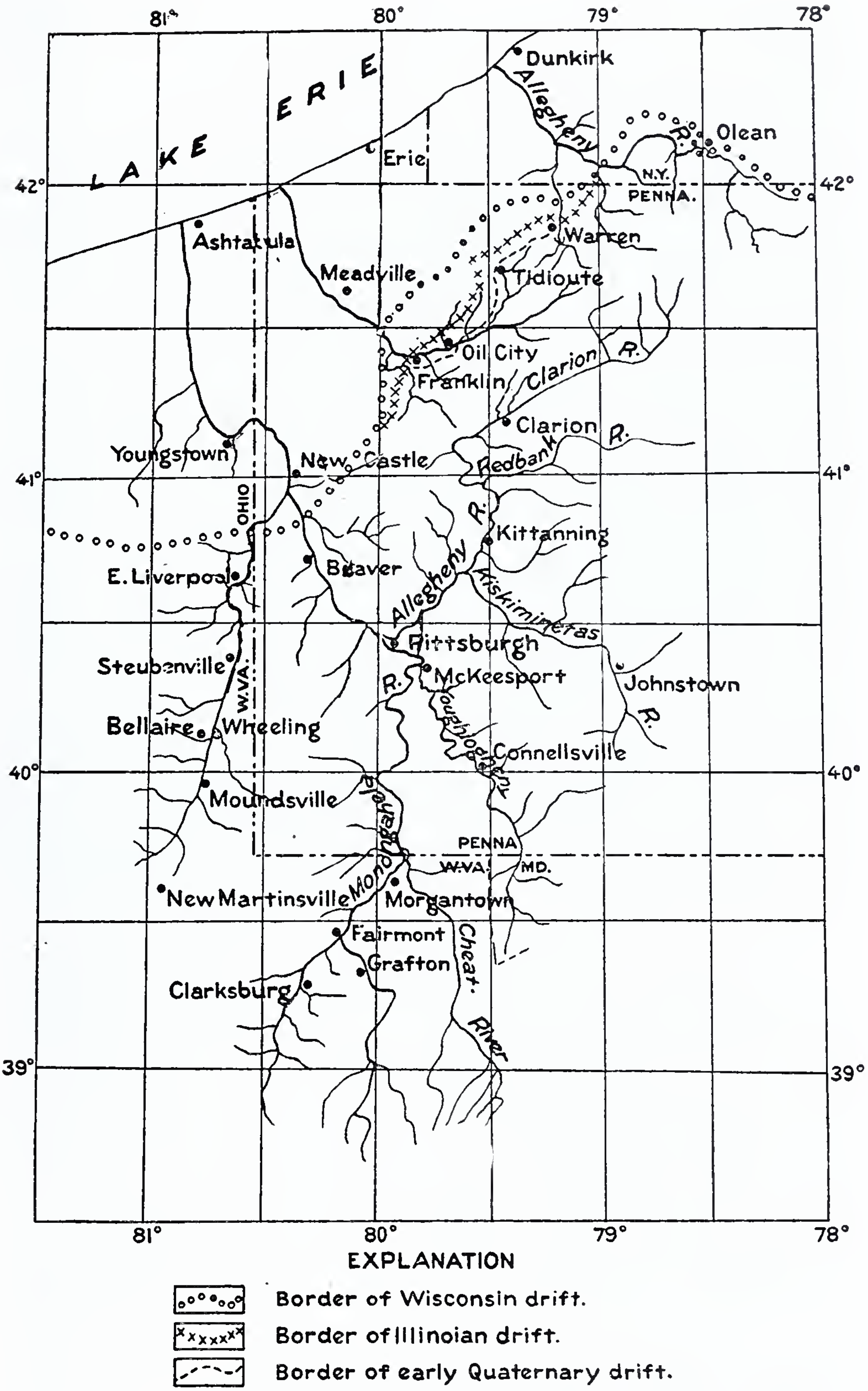

Figure 10.—Sketch map showing probable preglacial drainage of western Pennsylvania. (After Frank Leverett.)

Allegheny River and Old Upper Allegheny River, respectively. (See fig. 10.)

PLEISTOCENE AND RECENT TIME

ILLINOIAN DEPOSITION AND MAJOR DRAINAGE MODIFICATIONS

The Parker strath erosion cycle was terminated by the invasion of continental ice sheets which hitherto have been ascribed to the Kansan or pre-Kansan stage of the Peistocene or glacial epoch. Very recently, however, Leverett[31] has concluded that two stages of glaciation are represented by the deposits of these ice sheets, of which the older drift is very poorly preserved or entirely absent in the area covered by this report and the younger is to be ascribed to the Illinoian stage. The Illinoian ice sheet stripped vast quantities of rock waste from its path and deposited much of that débris as a sheet of glacial drift which now extends southward nearly to a line drawn through Beaver, Franklin, Tidioute, and Warren, as shown in figure 10. It overrode the northern outlets of the preglacial streams of western Pennsylvania and blocked them with ice or with permanent barriers of till. With their northward flow thus cut off, the preglacial streams from the south were ponded until their waters overflowed the gaps at the heads of tributary streams and sought escape along the ice front. Successive stream diversions were probably brought about in this way until the Old Upper Allegheny found outlet into the Old Middle Allegheny near Warren and Tidioute, and the latter stream in turn overflowed into the Clarion River south of Franklin. Simultaneously the Ohio overtopped its headwater divide in the vicinity of New Martinsville and escaped southward. In this manner the present Allegheny River was formed, the Beaver and Ohio rivers were reversed, and the drainage of western Pennsylvania was permanently diverted to the Mississippi system. Williams[32] has recently analyzed this stage of the history of the Allegheny River in some detail and has shown that the present stream comprises four valleys in which the flow is reversed and four trenched cols.

The water that flowed from the ice front transported a great volume of débris and dropped much of it upon the Parker strath in the Allegheny-Ohio Valley. The valley train built up in this manner attained a maximum thickness of at least 130 feet, as is shown by streamborne pebbles on the hillsides at this height above the strath. Outwash trains were not deposited in the Monongahela, Youghiogheny, and other major tributary valleys from the unglaciated province to the south, but the strath floor of those valleys is veneered locally by heterogeneous deposits of fine sand and silt with a few erratic boulders a foot or more in diameter. These deposits are called the Carmichaels formation. Campbell[33] has emphasized the local absence of Carmichaels deposits and the discordance in altitude of separated areas of these beds and has postulated local ponding of the streams above intermittent jams of river ice to explain their variable character and

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[31] Leverett, Frank, Researches in sedimentation in 1926-1927: National Research Council, p. 46, Washington, 1927.

[32] Williams, E. H., Jr., The deep Kansan pondings in Pennsylvania and the deposits therein: Am. Philos. Soc., Proc., vol. 59, pp. 49-84, 1920.

[33] Campbell, M. R.: U. S. Geol. Survey Geol. Atlas, Masontown-Uniontown folio (No. 82), pp. 3-4, 1902.

discontinuity. Shaw,[34] on the other hand, has concluded that the aggradation of the master stream with glacial outwash reduced the capacity of the tributaries to transport load and caused the Carmichaels beds to be deposited rather generally in the lower reaches of the tributaries.

During or after this period of aggradation the rivers straightened their courses locally, probably by trenching the low divides of oxbow meanders, which had been topped by ponded water. Instructive examples of such abandoned meanders exist on Allegheny River at Parkers Landing and on Monongahela River at Bellevernon and in the vicinity of Carmichaels and Masontown. (See fig. 10.)

INTERGLACIAL VALLEY CUTTING

After the Illinoian ice sheet retreated, the new-born lower Allegheny-Ohio River attacked the unconsolidated material of its valley train and removed all except those portions which cover the remnants of the Parker strath. The work of the river did not cease with the removal of the outwash deposits, however, but continued until a trench had been cut in the underlying rock to a depth of more than 200 feet in the vicinity of Pittsburgh. Upstream the trenching decreased in depth and died out rapidly above the mouth of Clarion River. The Monongahela, Youghiogheny, and other tributaries deepened their valleys to a similar extent.

In the Mississippi Valley the Illinoian glaciation was followed by the Iowan glaciation, but drift of the Iowan stage has not been recognized in western Pennsylvania, and presumably its ice did not advance over this region. Shaw and Munn[35] have differentiated upper and lower benches of the more recent of the glacial terraces along Ohio River below Pittsburgh and have concluded that the upper of these, a gravel-covered rock shelf which attains an altitude of 810 feet, is somewhat older than the Wisconsin glaciation. It is not possible, however, to correlate this terrace deposit with any stage of glaciation in the Mississippi Valley.

WISCONSIN DEPOSITION

A continental ice sheet again advanced over northwestern Pennsylvania during the Wisconsin stage and deposited its load of drift over most of the area covered by the Illinoian drift. The ice front lay nearly parallel to that of the Illinoian stage but not quite so far south. The outwash from this ice sheet formed a frontal apron of boulders, coarse pebbles, sand, and clay from which a valley train extended down the Allegheny and Ohio rivers and filled that channel to a maximum depth of at least 100 feet with material that became progressively finer downstream. The original upper surface of this valley train is marked by terrace remnants as much as 80 feet above the present flood plain of the stream and, in the vicinity of Pittsburgh, slightly more than 800 feet above sea level.

Contemporaneously with the aggradation by the master stream

[34] Shaw, E. W., High terraces and abandoned valleys in western Pennsylvania: Jour. Geology, vol. 19, pp. 140-156, 1911.

[35] Munn, M. J.: U. S. Geol. Survey Geol. Atlas, Sewickley folio (No. 176), p. 7, 1911. Shaw, E. W. and Munn, M. J.: U. S. Geol. Survey Geol. Atlas Burgettstown-Carnegie folio (No. 177), p. 6, 1911.

Monongahela River and other major tributaries built up the lower reaches of their valleys by depositing the fine waste derived from erosion of the headwaters. Broad terraces similar to those of the Allegheny Valley were formed, but wholly from material indigenous to the drainage area.

RECENT DOWN-CUTTING AND DEPOSITION

Since the Wisconsin glaciation the streams of the Allegheny and Ohio basins, although greatly shrunken in volume, have begun the task of clearing their channels of the Wisconsin outwash. As yet, however, they have removed but little of this valley train, and they now occupy slightly tortuous beds trenched below its surface. During this postglacial interval the streams have reworked the upper portion of the Wisconsin gravel, introduced other alluvial débris of local derivation, and deposited the mixture as they overflowed their banks from time to time. In this manner there have been developed the present flood plains, conspicuous examples of which in the vicinity of Pittsburgh are the flat surfaces of Neville and Brunot islands and the mile-wide plain northeast of McKees Rocks. Except as it has been modified by the activities of man, the development of this flood plain and the reworking of the Wisconsin gravel are in progress today.

In proportion to their size many of the tributaries have much broader flood plains than Ohio River, that of Chartiers Creek at Rosevale measuring nearly half a mile. The explanation probably lies in the fact that the major streams have been heavily loaded with glacial débris during much of the time and hence have not been able to do as much lateral cutting as the tributaries, whose work has not been conditioned by heavy load but rather by clogged outlets to the master stream. The broad flat at Rosevale, for instance, stands at an altitude just a little above that of the Wisconsin terrace on the Ohio, and its breadth is apparently due to the fact that the creek has been held at approximately the same altitude since the beginning of the Wisconsin stage. Downstream from Rosevale the creek built up its bed during the Wisconsin aggradation and then cut it down again in sympathy with the Ohio. Upstream it has probably been cutting down without interruption.

GEOLOGIC STRUCTURE

REGIONAL FEATURES

The structural feature of first magnitude in southwestern Pennsylvania and adjacent regions is the broad, shallow spoon-shaped depression that lies between the Cincinnati geanticline on the west and the Appalachian uplift on the east. Its axis passes through Pittsburgh, strikes thence S.30°W. to the southwest corner of the State, and, passing into West Virginia, swerves S.45°W. through the Kanawha Basin parallel to the trend of the Appalachian folds. The deepest portion of the trough lies in southwestern Greene County, Pa., and the contiguous portion of West Virginia. Northward and southward the axis rises gently, so that successively older formations crop out in concentric elliptical bands about the center of depression. The area covered by this report occupies approximately the northeastern quadrant

of the depression, within which the rocks dip at low angles radially toward the corner of the State.

Superposed upon this trough are a number of secondary subparallel folds, which in the western half of the trough are very gentle but toward the east become progressively deeper and closer. The amplitude of these secondary folds being greater than the inclination of the flanks of the major depression, the details of geologic structure are somewhat complex and obscure the radial inward dip of the beds. The Pennsylvania quadrant of the trough may be subdivided into two structural provinces on the basis of the types of secondary folding, that of the eastern province being notably closer, deeper, and more nearly linear. These provinces coincide in a general way with the two physiographic districts that have been outlined above—the Kanawha and Allegheny Mountains sections of the Appalachian Plateaus.

Very recently the structural features of southwestern Pennsylvania in relation to those of contiguous parts of Ohio, West Virginia, and Maryland have been described by Richardson.[36]

The geologic structure of southwestern Pennsylvania has been represented on the accompanying map (Plate I) by contours, or lines connecting points of like altitude, drawn to show the lower surface of the Pittsburgh coal, at the base of the Monongahela formation, and of the Upper Freeport coal at the top of the Allegheny formation. These lines show the height of the index surface above sea level at any point and consequently show also the horizontal plan of the structural troughs and arches and the rate of slope of the beds. By difference from the altitude of a similarly located point on the land surface, they show the thickness of the rocks that lie above the index surface, or, in those areas in which the stratum has been worn away by erosion, its original position above the present surface. As the post-Mississippian strata are approximately parallel to one another, the altitude of any one of these strata and its depth below the surface at any point may be determined from the map if its interval above or below the index stratum is known.

Except within those small areas in which the altitude of the index surface has been determined precisely from coal-mine surveys and the records of deep borings this method of representation involves two sources of error. First, errors which may or may not be compensating and are probably less than the interval between successive contours arise in identifying an outcropping bed, determining its altitude, and calculating therefrom the altitude of the index surface by adding or subtracting a standard or average interval, which may differ from the actual interval. Second, in the eastern and northern parts of the region a cumulative error is introduced by the facts that the strata thicken toward the east—as is pointed out in some detail in the subsequent discussion of the sequence and water-bearing properties of the rocks—and that the calculated altitude of the index surface at any point in these parts of the region must be based upon a standard interval determined closer to the center of the primary basin. However, this cumulative error is not of serious magnitude within a small area,

[36] Richardson, G. B., Structure-contour maps of the Pittsburgh-Huntington Basin; Geol. Soc. America Bull., vol. 39, pp. 543-554, 1928.

and the contours as drawn show the actual deformation of the strata that lie at or near the surface.

SECONDARY FOLDING IN THE KANAWHA SECTION

The secondary structural features in the Kanawha section comprise a number of nearly parallel folds whose axes strike N.30°-50°E. and plunge southwestward ½° or less. The individual folds are very gentle plications whose axes are somewhat ill-defined and crooked in the western part of the section but are more nearly stright in the eastern part. It is noteworthy that the axes of the Nineveh syncline and its essential continuation, the McMurray (Boggsville) syncline constitute the axis of the first-order regional downwarp. Most of the folds are symmetrical; the dips of the flanks are usually less than 2° and over extensive areas do not exceed ½°. The amplitude of the folding is rather variable and ranges from less than 50 feet to more than 600 feet, although successive troughs and crests usually show a progressive increase in altitude above sea level away from the axis of the primary fold. The total structural relief, however, is much larger. The map (Pl. I) shows that the index surface descends from an altitude of 2,250 feet above sea level in northeastern Butler County to slightly less than 100 feet in southwestern Greene County. One unusual feature, which has a marked local influence upon the occurrence of ground water, is the Cross Creek syncline, a relatively close fold whose axis strikes N.80°W., transversely between the Nineveh and West Middletown synclines, in northwestern Washington County. To the south rises the transverse Westland dome, perhaps the broadest of the secondary folds, against whose southern flank the Claysville and Washington anticlines die out. These transverse structural features constitute a most effective local ground-water dam.

This area of gentle folding is bounded on the east by the Port Royal-Elders Ridge and Lambert synclines, asymmetric folds whose axial planes dip 1½° E. and have an average strike of N.30°E. This compound axis is near the western boundary of Fayette and Westmoreland counties and 10 to 15 miles west of the base of Chestnut Ridge; it crosses the Monongahela Valley 3 miles north of Masontown, the Youghiogheny Valley at Fitzhenry, and the Kiskiminetas Valley 2 miles west of Saltsburg. Southward the fold enters eastern Greene County and dies out about 6 miles north of the Pennsylvania-West Virginia boundary.

SECONDARY FOLDING IN THE ALLEGHENY MOUNTAINS SECTION

In the eastern part of the Kanawha section and throughout the Allegheny Mountain section the secondary folds differ from those to the west in being deeper, closer, and more nearly linear and in having axes that are almost horizontal. They are similar to the gentle folds of the area to the west in being symmetrical and nearly parallel. The axes strike N.15°-45°E., and the flanks attain a maximum dip of 15°. The amplitude of folding ranges from 700 to 3,000 feet within the area investigated and in general increases toward the east. The minimum amplitude exists between the Fayette anticline and the saddle that separates the Uniontown and Latrobe basins, and the maximum between the Uniontown syncline and the crest of the Dulany anticline.

Although these folds are distinctly linear, each comprises a succession of canoe-shaped prominences or depressions, which mask the general structural features unless close scrutiny is given to an extensive area.

GROUND WATER

GENERAL FEATURES [37]

SOURCE AND OCCURRENCE

The direct source of most ground water lies in water precipitated upon the land surface in the form of rain or snow. Immediate disposition of such precipitated water is effected by run-off into surface drainageways, by evaporation from wetted surfaces, and by absorption into the soil. The proportion of run-off is a factor of the rate, quantity, and form of precipitation, the relief and slope of the land, the absorptive capacity of the soil, and the nature of the vegetation. Evaporation is conditioned chiefly by the temperature, humidity, and barometric pressure and by the wind velocity at the wetted surface. The portion absorbed by the soil becomes temporarily a part of the so-called suspended or vadose water of the zone of aeration—that upper zone of soil and rock which is not permanently saturated with water under hydrostatic pressure. The suspended water is in turn disposed of by evaporation from the soil, transpiration from the plants, or percolation downward to the zone of saturation, in which the interstices of the rocks are filled with water. The water stored in the zone of saturation is termed ground water or phreatic water; it constitutes the supply for springs and wells.

The upper surface of the zone of saturation is known as the water table except where that surface is formed by an impermeable stratum. The water table is almost everywhere a gently undulating surface, which does not remain in a fixed position but fluctuates slowly with variable increments to and withdrawals from the body of ground water. In southwestern Pennsylvania, where there is relatively little variation in precipitation (see fig. 4), the influx of water to the zone of saturation fluctuates chiefly with the seasonal variations in the rate of evaporation and transpiration. Hence the water table is generally lowest late in the summer and highest early in the spring. Its position is shown by the level at which water stands in wells when they are not being pumped. In the consolidated rocks of this region, recognition of the water table may be difficult, inasmuch as water occurs in permeable beds at several different depths, and at many places the water in the deeper beds is under a lower hydrostatic head. The water of the zone of saturation, or at least of its upper part, is not in a wholly static condition but moves in the direction of the slope of the water table, or hydraulic gradient, from areas of intake to points at which it is discharged by evaporation or through springs and wells.

In some places a body of ground water is "perched" on an impermeable stratum, below which there may be unsaturated permeable rock. If in drilling a well the impermeable bed beneath a perched water body is penetrated, the water will be drained into the unsatur-

[37] For a more adequate treatment, see Meinzer, O. E., The occurrence of ground water in the United States, with a discussion of principles: U. S. Geol. Survey Water Supply Paper 489, pp. 1-192, 1923; Outline of ground-water hydrology, with definitions: U. S. Geol. Survey Water-Supply Paper 494, 1923.

ated permeable rock below, and the well may not yield water until it reaches the main body of ground water. Perched ground water apparently exists at some places in the high-level deposits of glacial outwash in the valleys of the Allegheny and Ohio rivers and also in the weakly permeable Carboniferous shales and shaly sandstones, but it is not everywhere clear whether the underlying rocks are unsaturated or merely impermeable.

If the ground water near the surface has a greater pressure head than the water at lower horizons but is not separated from the deeper water by any zone of unsaturated rock, the upper water is said to be semiperched. If a well is drilled in an area of semiperched water the water level in the well will fall as the drilling progresses. Semiperched bodies of ground water are the rule in southwestern Pennsylvania, at least in the strata that lie above the surface drainageways.

RELATION TO CHARACTER OF THE WATER-BEARING MATERIAL

Water in Unconsolidated Deposits

The principal unconsolidated deposits in southwestern Pennsylvania consist of clay, sand, and gravel that were laid down in the valleys as glacial outwash or ordinary alluvium, largely by fluctuating streams. Hence a certain locality may have received at one time coarse, flood-borne gravel and shortly afterward only silt or clay, which covered the gravel or filled its interstices. In part also these deposits were laid down by glacial streams which were so heavily burdened with rock waste that particles of all sizes were dropped together. However, bands of rather coarse and well-assorted material were deposited at some places along the axes of the swiftest streams, with the finer and heterogeneous materials on each side. As the streams aggraded their beds they probably migrated back and forth across the valleys, so that the coarse and well-assorted deposits were buried successively beneath finer and denser material. Consequently the unconsolidated deposits consist largely of a matrix of fine particles that incloses pipes and discontinuous sheets of coarser and better-assorted material, which serve as arteries of ground water. Hence the development of the ground-water supplies consists of searching for these water-bearing pipes and lenses, of which several may be penetrated by a single well. Even the best water-bearing beds may contain a considerable portion of fine particles which greatly reduce their permeability. Under such conditions, the yield of a well can be greatly increased by removing the finer particles from about the well. (See chapter on Finishing Wells.)

Water in Sandstone

Sandstone is merely indurated sand, and its water-bearing properties are to a great extent analogous to those of sand deposits in being conditioned largely by the size of grain and the degree of assortment. The water-bearing properties of sandstone, however, also depend on the amount of cement which binds the grains together, as the cement reduces the total pore space and thus the permeability. As the proportion of cement increases it may close many of the passages connecting adjacent interstices and eventually fill all voids completely. Much of the sandstone in southwestern Pennsylvania has been formed

from ill-assorted, earthy sediments of small grain size and is so thoroughly cemented as to retain little porosity. Many such rocks are impermeable under any ordinary hydrostatic pressure, and water can circulate in them only along bedding planes or at their upper and lower surfaces. Certain sandstone beds, however, are coarse and well assorted and have a high specific yield. Still other beds, which are on the whole not very permeable, inclose pipes and lenses of coarse, well-assorted material that is highly permeable.

The water-bearing properties of a sandstone may also be modified by solution of the cementing material or in highly indurated varieties by the development of joints. If the cement consists of calcium carbonate it may be taken into solution by ground water that contains dissolved carbon dioxide, and the porosity and permeability of the rock may be increased accordingly. This action is most rapid when the topographic and structural environments are such as to induce a vigorous ground-water circulation. Most of the sandstones of southwestern Pennsylvania, however, contain a siliceous cement which does not pass into solution with sufficient rapidity to make this process an effective agent in modifying the water-bearing properties of the rock. Furthermore, many of the massive sandstones of the area are extensively jointed, particularly along the axis of folds. Even a rock that has little or no original permeability may yield water from joint openings. (See fig. 27, p. 164).

Water in Limestone

Although a newly deposited calcareous sediment may contain a large proportion of interstitial space, the solution and recrystallization that accompany compaction may ultimately produce a limestone with very little original porosity. Such an impermeable rock, however, may be rendered permeable by joints or fractures which are produced by crustal deformation or by other causes; it may also be rendered permeable by the development of solution passages. Most of the joints in limestone are nearly vertical and form two intersecting sets which serve to divide the rock into blocks. The joints may be open near the surface but generally become tighter with increasing depth. Solution passages in limestone result from the solvent action of circulating ground water charged with carbon dioxide. They usually follow preexisting joints or bedding planes. Where the rock is deeply buried and the ground-water circulation is sluggish, or where the rock has not been long subjected to solvent action, the solution passages may be few and small. If, on the other hand, the topography and geologic structure have favored rapid circulation and conditions have been stable over long periods the rock may be rendered cavernous. Solution proceeds most rapidly above the water table, where downward movement of the water is relatively vigorous and the supply of carbon dioxide is adequate. Below the water table the content of dissolved carbon dioxide and, consequently, the solvent power of the water become depleted. The largest yields are obtained from limestone that has been depressed with relation to the water table, so that its upper, cavernous part has become submerged and saturated.

The limestones of southwestern Pennsylvania are thin bedded and comprise layers of dense, fine-grained limestone from about 2 inches

to 3 feet thick parted by layers of soft calcareous shale a few inches thick. (Fig. 24, p. 135). These rocks have not been extensively jointed, because the dense layers have broken independently, and most of the deformation has been effected by differential movement on the soft shale partings. Locally there has been some jointing along the axes of folds, but the joints are tight where they occur beneath 200 feet or more of overlying rocks and they do not yield much water. During all late geologic time the region has suffered progressive uplift, and the streams are even now in a youthful stage of erosion. Hence there has been no opportunity for large solution passages to be developed and then brought into the zone of saturation by subsidence. Small solution passages, which have been formed in the easily corroded partings of the more shaly beds, are the only secondary interstices in these rocks that furnish much water. These passages are largest and most numerous along the flanks of folds, but they do not follow down the dip of the beds much more than 50 feet below the level of the near-by surface drainageways. Where the thin-bedded limestones lie beneath thicker cover they are not usually water-bearing. In many parts of the area, however, these rocks are an important source of small water supplies.

Water in Shale

Although silt and clay, from which shale is formed by induration, may be composed of well-assorted particles and have a high porosity, their interstitial spaces are so minute that they are virtually impermeable, and almost none of their water will drain out. A small amount of water may circulate along the bedding planes and joints of shale formations, so that they may yield small supplies that may be valuable where no better source is at hand. In this area shale is the most common rock, and in many localities it is difficult to obtain large supplies of ground water. Many of the shale formations, however, are sandy and locally are composed of alternating bands, usually less than 12 inches thick, of fissile shale and dense earthy sandstone—the so-called "slate and shells" of the well driller. (See fig. 32, p. 180). Such rocks are somewhat brittle and are usually jointed, as shown in Figure 31, (p. 179). They carry ground water chiefly at the upper and lower surfaces of impermeable sandstone lentils and in the joints. Usually a well 100 feet or more in depth will encounter several sources of ground water, although the openings become notably fewer and tighter with increasing depth, so that drilling to a depth of more than 150 to 200 feet in such beds in search of an increased yield does not promise success. The depth and water-yielding capacity of the sources vary most erratically. In many wells, particularly those drilled far above the level of surface drainageways, the uppermost bodies of ground water are semiperched or possibly perched, and bodies of water at greater depths have successively lower and lower pressure head.

RELATION TO LAND FORMS

The shape of the land exerts a direct influence upon both the quantity and the quality of the ground water. Where the land surface is flat and has little relief over extensive areas, the water table is also flat and probably rather close to the surface. Conse-

quently the ground water is sluggish and, standing for a long time in contact with the rock, becomes highly concentrated if there is much soluble mineral matter present. However, if readily permeable strata are present, the quantity of ground water available to drilled wells is likely to be large. If, on the other hand, the area possesses considerable local relief, as southwestern Pennsylvania does, the surface drainageways are likely to be cut below the water table as it exists beneath the interstream areas. Under such conditions the water-bearing strata may discharge on the slopes of the valleys in the form of hillside springs, and the ground water circulates vigorously. Furthermore, the water table beneath the interstream tracts tends to become depressed to the level of the surface drainageways, although the tendency is not fully realized in rocks whose average permeability is as slight as that of the Carboniferous strata in southwestern Pennsylvania. Where the circulation is vigorous the soluble matter is completely leached from the rocks in course of time, so that the amount of dissolved matter in the ground water may become very small. The tendency toward drainage of the rocks that lie above stream level greatly reduces the quantity of ground water available, although its recovery is facilitated by the existence of natural discharge.

RELATION TO GEOLOGIC STRUCTURE

In southwestern Pennsylvania the Carboniferous strata are deformed by a number of secondary folds which are superposed upon one quadrant of a major spoon-shaped trough. (See chapter on Geologic Structure.) The change in altitude of any particular stratum is about the same as that of the Pittsburgh coal within any area of moderate size and hence may be read from the geologic structure map (Pl. I) with a fair degree of precision. A water-bearing bed may be raised above the water table on the crests of the anticlines and depressed into the zone of saturation in the synclines, and the water table also departs notably from a level surface, so that the areas in which the bed is a source of water supply can not readily be traced. Locally a body of ground water may be perched above an impermeable bed in the axis of a syncline far above drainage level. On the other hand, the less permeable rocks may be wholly devoid of water along the crests of anticlines.

The height to which water will rise from any particular stratum in a well is conditioned chiefly by the hydrostatic pressure of the water standing in the limbs of folds. Hence, as a rule, the water will rise higher above the water-bearing bed in wells along the axes of synclines than in wells along the axes of anticlines. Moreover, the rate at which a well will yield water is approximately proportional to the distance the water level in the well is drawn down by pumping, and the maximum yield is attained when the water level is drawn down to the top of the water-bearing stratum. Other conditions being equal, therefore, a well located in a syncline has the greatest potential capacity. Furthermore, a well flows by artesian pressure only when the head in the water-bearing bed is sufficient to lift the water to the surface. Hence, flowing wells are most likely to be found in the lowest portions of synclines. Inasmuch as the secondary folds in the Kanawha section of the Appalachian Plateaus plunge toward the south-

west, however, a considerable pressure head may exist at the axis of an anticline if the water-bearing bed rises to a still higher altitude toward the northeast. Flowing wells so located occur in this area.

The most direct relation of geologic structure to the occurrence of ground water is probably in its control of the ground-water circulation. Many of the folds of small amplitude in southwestern Butler County and northwestern Allegheny County (See Pl. I) seem to offer no impediment to ground-water circulation in the deeper rocks. However, most of the folds of greater amplitude—such as the Westland dome, in northwestern Washington County, and the folds of the Allegheny Mountains section—are effective barriers against circulation transverse to the anticlines.

PROBLEMS RELATING TO DEVELOPMENT

SELECTION OF WELL SITE

The development of a ground-water supply comprises three principal stages—selection of a well site, construction of the well, and installation of pumping machinery. Several factors influence the selection of the well site. Wells for domestic supply should if possible be so located that all surface drainage leads away from the site, lest pollution by objectionable organic waste should occur. Convenience of distribution is an important consideration that is all too often given inadequate weight. In the areas of unconsolidated deposits, particularly the glacial outwash and alluvium of the major stream valleys, the presence of water-bearing beds can perhaps be inferred from the geologic setting of the prospective well site and from the records of near-by wells. In detail, however, these deposits are extremely heterogeneous, and the number of gravel beds—which constitute ground-water arteries—as well as their thickness, depth below the surface, and yield, change abruptly from place to place and can be determined only by drilling. Consequently, when a large yield is required from these deposits, selection of the well site should be preceded by a sufficient number of test borings to establish the position of the best water-bearing gravel deposits within the plot under consideration. The cost of such exploratory drilling is small compared with the cost of the permanent development and is much less than the loss resulting from an inadequate supply developed at an arbitrarily selected site. At many places in the industrial section about Pittsburgh, however, the value of the real estate involved is of paramount importance and may outweigh technical considerations.

METHODS OF WELL CONSTRUCTION

Dug Wells

The first ground-water supplies developed in southwestern Pennsylvania were obtained from dug wells in the unconsolidated deposits or in the surficial waste formed by the weathering of the sedimentary rocks. These wells were dug by hand and were walled with brick or dry rubble masonry. Such wells are especially numerous in the remnants of the early glacial (Illinoian) valley train of the Allegheny-Ohio Valley and in the glacial outwash deposits of northern Butler

County. The procedure has the advantages of not demanding extensive mechanical equipment or specially trained labor. Its disadvantages are the lack of sanitary safeguards of the water supply, which has led to the abandonment of most of these wells, and the small yield of the wells. Construction presents no serious difficulties where the material penetrated does not cave readily and the well is not sunk far below the water table. When loose caving sand or gravel is penetrated, temporary timbering and lagging must be erected as the well is sunk—an operation which is sometimes rather difficult. If, too, the well is to be dug to a level far below the water table in order to provide a large storage volume within the well or to reach additional water-bearing beds, it becomes necessary to maintain the excavation free of water. Obviously, an impasse is soon reached in which it is impossible to deepen the well against a mounting influx of water without extensive mechanical equipment. Consequently the development of large water supplies by deep dug wells in the alluvium of the major valleys is not feasible.

Caisson Wells

Caisson wells, which are usually larger than ordinary dug wells and may be 30 feet or more in diameter, are adapted especially to the recovery of large quantities of water from incoherent sand or gravel. In southwestern Pennsylvania they are useful only in developing ground-water supplies from the more permeable deposits of glacial outwash and alluvium. As their name implies, these wells are constructed much as a caisson is sunk to carry the foundations for a bridge or other structure below the water table. Construction involves the laying of a circular foot piece or shoe made of metal, or of timber provided with a metallic cutting edge; the erection thereon of a casing of porous concrete or other suitable material; and the excavation of the material within the casing. As material is excavated, the casing sinks of its own weight or is forced down by a superposed load, another section of casing is added at the top, and this operation is continued until the desired depth has been attained. Some skill is required to keep the casing vertical so that it will sink freely. If the ground is sufficiently stable a pit may be sunk to the water table, or to any convenient depth above, and the foot piece placed in the base of the pit before erection of the casing is begun. After the well has been sunk to the water table the material within the casing may be removed by an orange-peel bucket or other mechanical excavating device, by the methods of suction dredging, or by an air-lift pump. The air-lift pump is especially adapted to the removal of loose, fine sand, which may be replaced by well-assorted gravel or crushed rock after the method of making a gravel-screened tubular well.

The advantages of the caisson method of well construction are. first, a large volume of water is stored in the well to provide for fluctuations of draft; second, space is provided in which pumps may be installed so as to operate with maximum efficiency; third, a large infiltration surface may be provided on account of the large permissible diameter, so that the velocity at which water enters the well is low, and fine sand is not taken into suspension from the water-bearing bed. However, a low entrance velocity may be obtained in tubular wells by

adequate methods of construction, so that the last of these advantages is not peculiar to the caisson well. The disadvantages of the method are the large cost of construction, the space required for erection of the casing and manipulation of the excavating machinery, and the space occupied by the completed well. These disadvantages increase greatly as the diameter of the well is increased.

The caisson principle is also followed in the Cater and similar systems of well construction in incoherent material, to sink an outer casing of riveted boiler plate, perhaps 36 inches in diameter, to the top of the water-bearing bed. The well is then carried down into the water-bearing bed by the methods of constructing tubular wells.

Driven Wells

Wherever a bed of incoherent water-bearing sand or gravel exists at a shallow depth, small water supplies may be developed by means of driven wells. Such wells are constructed by driving a casing at the end of which is a drive point, a pointed solid drive shoe attached to a section of strainer pipe or screen, without first drilling or boring a hole for it. Driven wells are usually between 2 and 3 inches in diameter. Their depth is limited by the resistance of the material to penetration by the drive point and by friction against the sides of the casing, which increases rapidly until they are equal to the driving force that can be applied without danger of crumpling the casing. Under favorable conditions such a well may be driven to considerable depth if the pump cylinder is inserted in the casing string and placed below the surface. There are many driven wells in the glacial outwash of northwestern Butler County, but it has not been customary to construct wells of this type where the water table is much more than 25 feet below the surface. The capacity of a driven well is generally incapable of providing large supplies.

Drilled Wells

By far the greatest number of water wells in southwestern Pennsylvania are tubular wells that have been drilled by the cable-tool percussion method. Probably no other method of drilling is so well suited to the conditions in this area, particularly for drilling in the consolidated rocks. This method of drilling,[38] which was developed in the oil fields of Pennsylvania, employs a heavy chisel-edged drill bar or other tool suspended from a rope or steel cable to which a reciprocating motion is imparted by a suitable apparatus. The function of the drill bar is to crush the rock into fragments and to churn it into a sludge with water so that the fragments can be removed from the hole with a bailer or sand pump.

The equipment usually employed is the portable rig, commonly known in this area as a churn or cable-tool drilling machine. The essentials comprise a steam or gasoline engine or an electric motor, hoisting gear, cable reels, and walking-beam mechanism mounted on a compact sturdy frame which is supported on wheels so that the whole may be moved from place to place as a unit, either under its

[38] Bowman, Isaiah, Well-drilling methods: U. S. Survey Water-Supply Paper 257, 139 pp., 1911. A considerable part of the subsequent discussion of problems of well construction is adapted from Bowman's general treatment of the technique of well drilling.

own power or by an auxiliary means of traction. Each of these functional parts is under easy control by the driller from the front end of the machine, which is adjacent to the well site. Support for the hoisting sheave is provided by a pole or A-frame mast, which during drilling operations is erected at the front end of the machine with a slight forward cant so as to bring the sheave vertically above the well. While the machine is in transit the mast is lowered over the machinery. Formerly the frame and mast of all such well-drilling machines were constructed of timber, but very sturdy ones made wholly from structural steel are now obtainable. Outfits that combine mobility and effectiveness have been assembled by several enterprising drillers of the area by mounting a drilling machine on an automobile truck, and similar equipment is now available from several manufacturers. While a well is being drilled by such an outfit, the truck is fixed in position by blocking its wheels or, preferably, by sinking them into suitable shallow pits, and the frame of the rig, which protrudes somewhat beyond that of the truck, is supported by jacks or blocks so that the force imparted to the string of tools is not dissipated by the springs of the truck.

Portable well-drilling machines are constructed in a number of sizes adapted for drilling holes 200 to 1,000 feet deep. The rigs most frequently used in sinking water-supply wells are designed to drill a 6-inch or 8-inch hole to a depth of 500 feet and operate at high efficiency. By skillful manipulation, however, holes as much as 12 inches in diameter can be drilled to a depth of perhaps 250 feet, although the added weight of the larger tools taxes the durability of the machine and may require the substitution of a more powerful engine. Such a machine weighs, without tools, 12,000 to 14,000 pounds and carries a mast about 30 feet high. Large semiportable rigs weighing from 16,000 to 45,000 pounds and adapted to drilling wells from 1,500 to 4,000 feet deep are also manufactured, but they are used chiefly for drilling oil and gas wells.

In the cable-tool percussion method the motion of the tools is derived in part from the reciprocating motion of the walking beam and in part from the elasticity or stretch of the cable. The stroke of the walking beam may be varied by the driller, but in portable rigs the walking beam is made relatively short so that its stroke is short and is not capable of variation over a wide range. The stretch of the cable depends upon the weight of the drilling tools, the speed of the walking beam, and the type of cable, which may be manila or wire rope. The stretch varies directly with the length of the cable that is under the load of the tools and is much greater for manila rope than for wire rope. As the depth of the well increases the total stretch of the cable becomes equal to and then exceeds the stroke of the walking beam, so that skillful manipulation is required lest the machine "drill on the tools"—that is, lest the walking beam be coming up as the tools are going down. In drilling wells more than 200 feet deep many drillers control the total stretch by using a composite cable made by splicing a "cracker" of manila rope 50 to 100 feet long to the lower end of a relatively inflexible wire rope. By proper adjustment of the distance and speed that the walking beam travels and by using a less elastic cable, drilling may be continued, with considerable loss of efficiency, to as much as twice the rated

depth capacity of the machine. Over most of southwestern Pennsylvania supplies of potable ground water are not to be expected more than 500 feet below the surface, so that the limit of efficient operation of the portable well-drilling machine is not likely to be exceeded.

The mast of the portable rig may be replaced by a timber or steel derrick such as is used with the so-called standard outfit of the oil fields, although the derrick used by the water-well driller is rarely more than 40 feet high, whereas that of the oil-well driller is usually 50 to 90 feet high. Such a derrick is more rigid than a mast and admits the use of tools of greater weight and consequently of larger diameter. It is not usually erected at a water well, however, unless it is to be retained permanently as a means of removing the pump and facilitating cleaning of the well.

Tubular wells are most easily constructed in unconsolidated materials, such as the alluvium and glacial outwash of southwestern Pennsylvania, by the hydraulic rotary system, the mud-scow or California system, or the use of earth augers of various types. The hydraulic rotary system is best adapted to drilling in clay, sand, and fine gravel, especially if the beds are slightly consolidated. The mud scow is suited to penetrating bouldery material or thick beds of gravel. The earth auger has a somewhat limited use in drilling holes of moderate depth through clayey material which does not cave readily. These methods have not been used generally in southwestern Pennsylvania, but they are so well suited to the conditions that exist in the unconsolidated deposits of the larger river valleys that they should receive thorough testing.

In the hydraulic rotary system of drilling, penetration is accomplished by the rotation of a cutting shoe or bit attached to the bottom of a string of tubing. The outfit comprises a derrick or mast similar to that of the cable-tool percussion outfit, a rotary table that grips the tubing firmly and yet allows the tubing to be lowered gradually as sinking progresses, an engine that rotates the table and tubing by means of suitable gearing and also operates the hoisting mechanism, and hydraulic or "mud hog" pumps. As the tubing and its shoe are being rotated, the hydraulic pumps force a sludge of water and suspended clay down through the tubing, out through openings in the bit, and up to the surface between the tubing and the walls of the hole. This circulating mud-laden fluid, whose maximum specific gravity is about 1.45, serves two purposes—it constantly removes the loosened material from the hole and also puddles up loose formations with a claylike deposit and gives them strength to resist caving. While a bed of clay is being penetrated the circulating fluid is kept as clear as possible, so that it will have the maximum capacity to transport the fine particles loosened. While a bed of sand or gravel is being penetrated, however, the fluid must be maintained at a high specific gravity.

When a water-bearing bed is entered with the hydraulic rotary tools, the pressure of the circulating fluid drops suddenly if the static level of the ground water is some distance below the surface of the ground. If, however, the static level of the ground water is near the surface, the pressure gage may not drop noticeably and the water-bearing bed may not be detected. A skillful driller, however, can prevent such a situation by running a small pilot hole or "rat hole" ahead of the full-sized hole in order to determine the character of the formation. A

further disadvantage of the method is that the water-bearing material may be so puddled with clay as to reduce its water-yielding capacity unless the well is very thoroughly cleaned.

The mud-scow or California system[39] of drilling differs most widely from other systems in the tool by which penetration is accomplished. This tool is the so-called mud scow, which is similar in shape to the bailer or sand bucket used in the cable-tool percussion method and has a flap or dart valve at the bottom. It differs from the ordinary bailer in being much heavier, in carrying an annular cutting shoe at the bottom, and in being fitted at the top with a knuckle joint that permits easy dumping. For drilling in clay, the shoe may be modified by a diametrical chisel-like bit. The mud scow is a percussion tool which fulfills the functions of both drill and bailer when given a reciprocating motion. It is usually attached to a ½-inch wire cable by means of a rope socket, a box and tongue sub, a set of fishing jars whose stroke ranges from 24 to 36 inches, and a pin and tongue sub. The rig with which the mud scow is used is very similar to the portable cable-tool rig, except that the walking beam is placed at the top of the mast by some drillers and actuated by means of a long pitman. This arrangement of the walking beam allows more space for working about the well, but it is not the common practice in many places where the mud scow system is used.

In drilling the mud scow is given a reciprocating motion like that of the cable percussion tool, and in ordinary materials it may also be rotated to loosen the sand and gravel from inside the casing. When it is drawn up to be emptied the bucket is manipulated in such a way that the weight of the jars and connections assists in the dumping. Water is necessary for the drilling operation. The mud scow must not be run so long as to become filled, lest some of the excavated material spill over and become jammed between the mud scow and the casing and thus cause a difficult fishing job. Boulders too large to be picked up can usually be worked to one side of the casing shoe and side tracked by drilling on them with the mud scow, which takes up the finer material surrounding the boulder. If the boulders are unusually large and can not be passed in this fashion, a cable percussion bit is substituted for the mud scow, and the boulders are broken up. While drilling in loose material it is necessary to keep the water level as high as possible within the well and to carry casing down as fast as the hole is deepened in order to prevent caving. In very soft ground a hole much larger than the casing may form, and material falling from the top of such a cavity may crush a thin casing and cause the loss of the well.

CASINGS

General purpose and types

In general, the purpose of setting casing in water wells is five fold. First, it may be used to support beds of incoherent or brecciated material against caving, although it is rarely required to serve this purpose in the sedimentary rocks of southwestern Pennsylvania. Second, it may be used while drilling to carry a straight hole through inclined or creviced beds. Third, it may be used to prevent organic matter

[39] Schwalen, H. C., The stovepipe or California method of well drilling as practised in Arizona: Arizona Univ. Agri. Exper. Sta. Bull. 112, pp. 103-154, 1925.

or industrial wastes from entering the well by surface drainage or by seepage through the soil and weathered rocks. Fourth, it may be used to exclude from the well water of inferior chemical character. Fifth, if water is confined in the water-bearing bed under hydrostatic pressure, casing may be required to prevent loss of head by leakage into an overlying unsaturated bed.

In southwestern Pennsylvania water wells drilled in the sedimentary rocks are ordinarily cased with oil-well or screw-joint casing, which has strength to resist crushing and can generally be recovered from lost or abandoned holes. Moreover, if made of wrought iron or certain alloy steels, this casing is very resistant to rust when in contact with noncorrosive waters. The sizes most commonly used are 5⅝-inch and 6¼-inch casing and 6-inch standard pipe, although 8-inch and occasionally 10-inch casing are also used. Each size of this casing is available in different weights. Wherever the size of the standard couplings interferes with setting casing of the size desired, either inserted-joint or flush-joint casing may be used. In inserted-joint casing one end of each piece of casing is expanded about a quarter of an inch greater in external diameter than the rest and an internal thread is cut therein. Inserted-joint casing retains a fair degree of strength but should never be driven. Flush-joint casing, as the name implies, does not increase in diameter at the joints. So much metal is removed in cutting the threads for joints of this type that the casing is very weak and must be used with extreme care.

Wells drilled in unconsolidated deposits may be cased with oil-well or screw-joint casing as much as 15½ inches in diameter; steel casing as much as 36 inches in diameter may also be prepared by bending plates of the proper thickness into cylindrical form and butt welding, lap welding, or riveting the joints. Concrete and tile casing of several types are also available in several diameters, the largest about 36 inches. When it is desired to penetrate a stratum of sand or gravel that has not been puddled by mud-laden fluid, metallic casing may be driven as long as the friction of the material pressing against the outside of the casing is not too great. If vigorous driving is necessary, heavy drive pipe is generally used to avoid failure of the casing string at a joint. Such casing may also be bailed into place or be forced down by hydraulic jacks or by a superposed load, as in the caisson method of well construction. In bailing casing into place, the loose sand and gravel are excavated from within the casing by a sand bucket or mud scow, and the casing sinks of its own weight as long as the loose material outside moves freely downward and inward into the cavity created by the bailing.

Use of Cement and Clay in Setting Casings

Whenever the importance of the ground-water development warrants, and it is not necessary to provide for removing the casing from the hole subsequently, cement is the most effective means of setting the casing in place.[40] Cement is used in the form of a neat grout, which attains its greatest impermeability and strength when the least possible proportion of water is used in mixing. Although several factors

[40] Swigart, T. E., and Beecher, C. E., Manual for oil and gas operations: U. S. Bur. Mines Bull. 232, pp. 21-31, 1923. Hough, J. F., Cementing oil wells to shut out ground water: Eng. News-Record, vol. 100, pp. 392-394, March 8, 1928.

influence the consistency of the grout that can be placed successfully, a ratio of $4\frac{1}{2}$ to $5\frac{1}{2}$ gallons of water to a sack of cement is usually satisfactory. Care in maintaining a uniform consistency throughout the operation is rewarded by greatly superior results. If it is desired to obtain a grout of high early strength and to accelerate its initial set, between 2 and 4 per cent of calcium chloride with or without 7 to 10 per cent of calcium oxychloride may be added to the mixture, but the exact quantities of these accelerants to be used with any particular lot of cement should be determined by preliminary experiment.

Three methods of placing the cement grout are in common use in the petroleum industry—the dump-bailer method, the tubing method, and the casing method. Any of these methods can readily be adapted to water wells.

In the dump-bailer method the casing is first raised above the bottom of the hole an amount which is equivalent to the volume of grout to be used. The entire quantity of grout is then placed in the bottom of the hole by a bottom-dump bailer, the casing is filled with water, closed at the top, and lowered slowly to the bottom of the hole. The casing filled with water acts as a piston as it is lowered and forces the grout by displacement into the annular space between the outside of the casing and the wall of the hole. After the cement has set for 3 to 10 days the portion remaining inside the casing is drilled out. If the well penetrates permeable strata so that it cannot be filled with water, the casing can be closed at the bottom by a plug, filled with water to give added weight, and lowered to its seat. Thin cast-iron plugs of several types, which can be drilled out after the grout has set, are obtainable.

In the tubing method the casing is raised off its seat, and a string of pipe or tubing, usually 2 inches in diameter, is placed in the well with its lower end a few feet above the bottom of the casing. The annular space between casing and tubing is closed by a packing device at the lower end of the tubing or, after the casing has been filled with water, by a stuffing-box nipple at the surface of the ground. In placing the cement, water is first forced down through the tubing and up between the outside of the casing and the wall of the hole for several minutes in order to assure circulation and to clean out the hole. Circulation having been established, the grout is pumped into the tubing and forced to the bottom of the well by pumping in water above it. The annular space between casing and tubing is filled with water, however, so that the grout can not rise therein and moves upward outside of the casing. In the best practice pumping is stopped before the top of the column of grout has reached the bottom of the tubing, lest an excess of water should be forced into the cement. The proper time to stop the pumps is determined by one of the methods used in the casing method. After the grout has been placed the casing is lowered to its seat. The tubing cap is then opened, and the excess cement is flushed from the bottom of casing and tubing by pumping water into the casing and up through the tubing. Once it has been thoroughly flushed, the tubing is withdrawn, and the casing is filled with water and capped to hold the grout in place until it has set. If necessary, pressure can be maintained in the casing by means of the circulating pump until the grout has set.

The casing method is the same in principle as the tubing method

except that the cement is forced down through the casing rather than through auxiliary tubing. Its several modifications include the one-plug, two-plug or Perkins, and Halliburton processes. In some respects this method is superior to the other methods, but the operation requires a high degree of skill on the part of the driller if it is to be successful. In the first stage of the procedure the casing is raised 1 or 2 feet above the bottom of the hole, after which the top of the casing is connected by a swedge nipple to the force main of the circulating pump, circulation is established, and the hole is flushed with water for several minutes. The swedge nipple is then removed, and a bottom plug, so called, is inserted in the casing. This is a plug of soft wood whose lower end is almost as large in diameter as the casing and is fitted with rubber washers which fit the casing tightly. Also, the bottom plug tapers toward the top and is somewhat longer than the distance between the lower end of the casing and the bottom of the hole. After this plug has been inserted in the casing the swedge nipple is replaced, and cement grout is pumped in above the plug, which is thereby forced down the well and effects complete separation between the water or mud-laden fluid below and the grout above. When all the grout has been pumped into the casing, the swedge nipple is again removed and, in the two-plug or Perkins process, a top plug is placed above the column of grout, the nipple is replaced, and water or mud fluid is pumped in above the top plug. In this manner the two plugs and the intervening column of grout are forced down the casing as a unit until the bottom plug reaches the base of the hole. On account of its length this plug can not pass out of the casing, but the cement grout flows around its tapering upper part and is forced into the annular space between the casing and the walls of the hole. When all or nearly all of the grout has been forced into place the pumps are stopped and the casing is lowered to its seat. After the cement has set, the plugs are drilled up.

The success of the casing method of placing cement depends upon knowing the exact position of the grout column in the well at all times. In the one-plug process, which does not employ a top plug, this is determined by measuring the volume of all fluids pumped into the well and calculating therefrom the distance the grout column is forced down. In the two-plug or Perkins process the fluids may be metered, or it may be assumed that the pump will stall when the top plug reaches the bottom plug. In this process also a wooden bar several feet long, known as a spacer, may be run between the two plugs so that the pump will stall just before the top of the grout column reaches the bottom of the casing. More accurate, however, is the Halliburton process, in which the position of the top plug is measured by a steel tape or piano wire which passes through a special stuffing box at the casing head and is attached to a lead weight placed atop the plug.

Few drilled wells are so nearly straight and vertical that the casing does not touch the side of the hole at one or more points and that cement grout can be forced entirely around the casing. In the best oil-well practice, therefore, the casing is pulled back 20 or 30 feet and the hole is underreamed before the casing is cemented, so that a clear annular space 3 to 4 inches wide exists entirely around the casing for that distance at its bottom. Such procedure would, however, not usually be required in the relatively shallow water wells.

Casing may also be sealed in place with clay by using mud-laden fluid of very high specific gravity in place of cement,[41] the clay being placed as in the tubing or casing method of cementation. This method is very satisfactory under ordinary circumstances and is far more certain than pouring a sludge of bailings into the annular space outside the casing at the surface of the ground and allowing it to settle by gravity alone.

Casing problems in southwestern Pennsylvania

The usual practice in drilling water wells in the sedimentary rocks of southwestern Pennsylvania has been to drill through the soil and 2 to 5 feet into the solid rock a hole that is somewhat larger than standard. A string of casing, which is usually less than 25 feet long, is set firmly into the bottom of this hole, and drilling is then continued with a standard-gage bit. The open space outside of the casing is sealed against downward-percolating water by dumping into it the fine sludge bailed from the well as drilling progresses in the solid rock. This procedure seals the casing very tightly in place and is an adequate sanitary safeguard where the rocks consist of shale that is unbroken by joints. Massive sandstone may be so broken and fractured, however, that undesirable waste may percolate through it into the well. Certain springs supplied from the jointed massive sandstone pictured in Figure 27, have been found to yield water that is unsafe for drinking, even though the orifices themselves are adequately protected from direct pollution. Beds of limestone may not only be jointed but may be traversed by solution channels that allow polluted water to percolate readily from the surface. Hence, whenever a well is drilled into such rocks for a domestic water supply, every effort should be made to detect the presence of open joints, any of which may communicate with the surface. If joints are found above the water-bearing bed, enough casing should be inserted to extend below the crevices and should be tightly and permanently sealed in place.

In many parts of southwestern Pennsylvania iron-bearing waters are associated with beds of coal and other rocks, especially in the Allegheny formation. The presence of iron in amounts exceeding 1.5 parts per million is undesirable, so that such waters are usually shut off by casing and a supply of better quality sought below. When in contact with oxygen, however, such waters are corrosive and may attack the outside of the casing vigorously, especially at a joint, and corrode an entrance into the well. As a result, the quality of the water yielded by the well may be so seriously impaired that the well may have to be abandoned. Usually corrosion may be prevented by drilling a slightly larger hole through the bed yielding the corrosive water and effecting a shut-off by a casing that is very carefully sealed in place by either clay or cement. This procedure protects the metal by an unbroken external covering of noncorrosive material. Another means of excluding such inferior waters permanently from wells lies in the use of casing made from noncorrosive material such as concrete or vitrified tile. Such casings are widely used in the unconsolidated deposits of other regions, but so far as is known they have not been much used in wells drilled in consolidated sediments. The use of such

[41] Swigart, T. E., and Beecher, C. E., op. cit., pp. 33-35.

casing materials could profitably be made the subject of experiment with a view to evolving an adequate method of setting the tiles so that the joints would be water-tight. Wells 192, 202, 215, and 221 of Butler County (pp. 278, 284, 282, 266) and well 323 of Allegheny County (p. 214) are typical of those which have been cased through beds with iron-bearing water and have found water of good quality below. In many places the shallow iron-bearing waters are semiperched, and hence casing must be set with great care in order to be effective.

Many trying casing problems exist in the oil and gas fields in the area west of Chestnut Ridge. (See fig. 2.) The common practice in drilling oil and gas wells is to set a permanent casing when the deepest bed that contains fresh water has been penetrated and then to remove such temporary outer casing as may have been employed. This practice is adequate to separate the fresh and salt ground waters, but it leaves about the permanent casing an annular space into which shallow semiperched ground water may be drained where a large number of deep wells are drilled. In some places where semiperched ground water has been drained the deeper rocks are shaly and not water-bearing beneath continuous cover, and it is difficult or impossible to obtain an adequate domestic water supply from a drilled well. Obviously, extreme care should be used in casing the deep wells to protect the sources of rural domestic water supply.

The fresh ground waters may be contaminated by brine which seeps from defective or inadequate casings in the deep wells where the static level of the brine is higher than the bed which contains the fresh water, as in the southwest corner of Butler County, near Zelienople and Evansburg and in Allegheny County near Imperial and Midway. Contamination of the fresh ground waters may also arise from careless disposition of the concentrated brines that are pumped with the oil in most of the oil fields. In many places these brines are discharged from the separating tanks into the annular space between the casings or outside the permanent casing of the deep wells. This practice is not objectionable if the beds which contain fresh water are shut off by adequate casing which is known to be in good condition. It not infrequently happens, however, that the strata near the surface are not correctly correlated and that a bed which contains fresh water is not cased off and is exposed to infiltration of the waste brines. Also it is likely that the casings in some wells are corroded or otherwise defective. On the other hand, some domestic wells of the oil fields yield a contaminated water because they are themselves inadequately or defectively cased, and waste brine may enter them from the surface. Adequate and skillful casing of all wells, both deep and shallow, is the answer to these problems.

Both on account of the high value of real estate within the industrial section and of the desire to locate wells close to the present streams, many of the wells that are drilled in the alluvium and glacial outwash of the major valleys are so located that the collar of the well is submerged at ordinary river stages. (See fig. 21.) Inasmuch as the water of the river is polluted by sewage and industrial wastes, especially at low stages, it is desirable to prevent downward percolation of the river water around the casings of these wells. Prevention would probably be most readily effected by sinking an external casing of large diameter at least 10 feet below the bed of the river, or to a depth con-

trolled by the texture and water-bearing properties of the alluvium and sealing it thoroughly in place with cement grout or clay placed by the tubing or casing method. Drilling and finishing of the well could then proceed by using a smaller internal casing.

Many other wells are sunk into the alluvium from sites on flood plains upon which blast furnaces and steel mills were formerly located and which are now covered by old dumps of furnace slag as much as 30 feet thick. As is brought out on pages 118-120, these weathered slag deposits are likely to be saturated with water that is so highly concentrated as to be unfit for all ordinary uses, although the ground water of the underlying alluvium may be of good quality. Under such conditions, successful well construction requires complete segregation of the two waters. This segregation can be effected, wherever an extensive layer of impermeable clay is present near the top of the alluvium and not far below the base of the slag, by landing an external casing of large diameter in the clay stratum and very carefully sealing it through the slag by cement or clay. Sealing of the casing with one of these materials is necessary, for merely driving the casing into the clay, although effective for a short time, is not likely to prevent permanently the downward percolation of water from the slag. Fortunately the uppermost part of the alluvium that underlies the slag has a very low permeability, so that the technique outlined above should be widely applicable. If at any place there is no impermeable bed below the slag and the alluvium is permeable throughout, the entire body of ground water is probably of inferior quality, especially if the water table is in the slag.

FINISHING WELLS IN THE SEDIMENTARY ROCKS

The construction of wells in the sedimentary rocks of southwestern Pennsylvania involves few problems other than those presented by the water-yielding capacities of the different beds. Caving beds other than the surficial rock waste are very rare, so that difficult casing problems are uncommon. Standard practice is to drill at least 5 feet below the water-bearing bed in order to make a basin for the sludge which may collect. Wherever a well is wholly in shale and only a very small yield is obtained, drilling may be continued as much as 50 feet below the water-bearing stratum to provide within the well a storage reservoir of sufficient capacity to equalize ordinary fluctuations in draft.

Explosives have been used occasionally in southwestern Pennsylvania in an effort to increase the yield of water wells, the results ranging from marked success to loss of the well. Shooting wells is not considered wise practice under most conditions, although it is sometimes justified as a last resort in the search for an adequate supply. Several fundamental principles should be observed. Explosives should not be used in a well that does not extend below local drainage level, inasmuch as a large portion of the ground water that occurs above the level of the surface drainageways is in the perched or semiperched condition. If shooting such a well should fracture the surrounding rock so extensively that communication with an underlying bed was established, the water level in the well might fall and the well might even be completely drained as in well 314 (p. 242). Explosives are not usually effective in beds of soft shale or very friable sandstone, because the

shooting only compacts the rock and forces small particles into the larger interstices. In general, explosives have the greatest effect in the brittle rocks, such as dense or earthy sandstones, very sandy shales, and heavy-bedded limestone. Shooting a well in such rocks may open extensive fractures about the well and add materially to the yield, although success or failure is largely a matter of chance. To be most effective, the charge of explosive should be as compact as possible and should be detonated opposite or just below the water-bearing bed. It is essential, therefore, that the depth of the water-bearing bed below the surface should be accurately known so that the charge may be lowered to the proper point in the well.

On account of its speed of combustion and its relatively small volume, nitroglycerine is the ideal explosive for the purpose, although its use is attended by considerable hazard and should not be attempted by one inexperienced with its properties or not properly equipped for handling it. Dynamite can be used with little hazard and usually with good effect. The usual tendency is to underestimate the quantity of explosive required. From 25 to 50 pounds of 60 per cent dynamite or an equivalent quantity of nitroglycerine is desirable for a well between 100 and 200 feet deep where the well is not close to a building or other structure that is subject to damage. The effect of the explosive is increased if the charge is detonated under as high a column of water as can be maintained in the well. The beneficial results of the detonation may not appear immediately, and it is usually necessary to run the tools back into the well and agitate thoroughly and drill out the material loosened by the explosion.

FINISHING WELLS IN THE UNCONSOLIDATED ROCKS

The success or failure of wells in unconsolidated materials, such as the glacial outwash and alluvium in the valleys of the larger streams in southwestern Pennsylvania, is dependent largely upon the method of handling the water-bearing beds. To be adequate, the method of construction must prevent caving of the water-bearing material and prevent entrance into the well of particles of sand or gravel in such volume as to clog the hole and thus reduce the yield or to damage the pump by abrasion. At the same time, the construction must be such as to offer the least possible resistance to the flow of water into the well. These conditions are usually met by screens, of which many types are in use. The variations in the depth and thickness of the water-bearing beds and in the texture and coherence of the material are so great and the possible combinations of these factors are so many that each well presents its own problem of screening, which must be solved on the ground. The successful solution of this problem depends on the skill and experience of the driller in selecting and placing the screen best suited to the conditions. The following discussion seeks to establish such general principles as will serve as a guide to more adequate screening practice in the area.

Screens

The quantity of water which enters a well under a given head varies with the area of the screen in contact with the water-bearing bed, and, conversely, for a given yield the velocity at which water enters the

well varies inversely with the area of the screen. However, the ability of water to transport particles of sand decreases very greatly with a moderate decrease in velocity, so that the probability of the screen becoming clogged or of sand being drawn into the well is lessened as the entrance velocity is lessened. Hence, the length of screen should be as great as the thickness of the water-bearing bed in order to reduce the velocity of entrance to a minimum. Moreover, of two screens of the same diameter and length, that which provides the greater area of inlet ports more uniformly distributed over the surface of the screen will allow water to enter the well with the less velocity.

One of the simplest types of well screens is the perforated casing, which may be prepared before it is put down if the depth and texture of the water-bearing beds are known. In standard oil-well casing round holes may be punched or drilled and slots may be punched or cut with a cold chisel or oxy-acetylene torch. Casing that is perforated in the shop by machine punches possesses the advantages that more perforations can be cut and a standard size of perforation can be maintained. Large casings made from sheet metal may be punched in the flat before shaping and riveting. Whenever it is mechanically feasible, the casing should be so punched that the burr and the smallest dimension of the perforation are at the outside of the casing. If the perforations are made in this way particles of sand are more likely to pass through into the well without becoming jammed. A section of casing is greatly weakened by being perforated and is therefore more easily crushed than the remainder of the string of casing.

The common practice in southwestern Pennsylvania is to perforate the casing before inserting it in the well, by drilling about 500 holes between a quarter and half an inch in diameter and about 2 inches apart from center to center. Usually from 5 to 7 feet of casing is perforated in this manner, with the lowest perforations between 1 and 2 feet above the bottom of the casing. Where the alluvium contains thin water-bearing beds such a screen may admit all the water that the formation will yield. However, where a single thick bed of water-bearing gravel is being developed it is very doubtful whether such a strainer will admit freely all the water which the bed is capable of transmitting. If it does not, a considerable friction head is added to the load on the pump whenever the well is pumped to capacity.

After casing has been set in the well it may also be perforated with a device which is lowered to the proper point in the well and, when actuated from the surface, forces a knife through the casing. The size and shape of the knife control the size of the slot cut, but small perforations are made with difficulty because small and consequently weak knives must be used. A slot about 3/8-inch wide and not more than 4 inches long is common. Many types of casing perforators are used, but the four-way perforator, which pierces the casing at four equally spaced points simultaneously, is preferable, for the use of a two-way or one-way perforator in soft sediments may deform the casing to an elliptical cross section, with the result that the knives may fail to penetrate it.[42] With most types of perforators a skillful operator can cut as many as eight slots to the round and place a round every 6

[42] Clark, W. O., and Riddell, C. W., Exploratory drilling for water and use of ground water for irrigation in Steptoe Valley, Nevada: U. S. Geol. Survey Water-Supply Paper 467, pp. 59-60, 1920. Schwalen, H. C., op. cit., pp. 136-144.

inches in a well which is 6 inches or more in diameter and not too deep. Perforations made in this manner have the wider side inward, so that a particle which can enter a slot is not likely to clog the screen.

In order that this operation may be successful it is necessary to note the depth, thickness, and texture of each water-bearing stratum as the well is drilled. The casing is then perforated opposite each stratum which it is desired to tap, the size of perforation being controlled by the size of particles in the stratum. Fine material may run into the well in such large amount through the first perforations that the operation must be interrupted long enough to remove the tools and bail out the accumulated sand.

Special patented screens are also manufactured, which have smaller openings than can be made by perforating a casing or provide a larger infiltration area and yet retain adequate strength. Among the better-known types are wire-wrapped screens, slotted tubular screens, die-stamped screens, and concrete screens.

Wire-wrapped screens consist of an inner shell which is made by drilling or punching a large number of holes in a piece of casing, pipe, or special tubing, and an outer layer of wire which is wrapped spirally about the shell. The space between successive turns of the wire is uniform and is governed by the grain size of the sand to be screened—usually between 0.004 and 0.1 inch. The wire used in certain patented screens has a trapezoidal, triangular, T-shaped or other special cross section and is wound with its wider face outermost so that the slots between successive turns of the wire are wider on the inside. In most screens of this type the wire is made of a noncorroding metal, but the inner shell may be either of steel or some noncorroding metal.

One common type of slotted tubular screen consists of a piece of tubing in which slots are cut with a milling machine, the size of opening generally ranging between 0.004 and 0.1 inch. The cross section of the slot used by different manufacturers also varies greatly, but in all types the wider side of the slot is inward. Another type of tubular screen has a continuous spiral slot made by assembling a machined metal band spirally about a cylindrical frame, the cross section of the band being such that each turn interlocks with those above and below and yet provides ample infiltration area. Still other tubular screens are made by inserting slotted or perforated disks in large perforations cut in a piece of casing or pipe. Usually the slotted tubular screens are made of noncorroding metal such as brass or bronze.

Die-stamped screens are manufactured under several patents and vary in details of construction, but all are designed to afford large inlet ports without weakening the screen by the removal of metal. Each inlet port is a louver-like opening formed by shaping the metal over a die in such a way that the strength of the casing is not greatly decreased. Screens of this type are well suited for use in coarse gravel and may be constructed from seamless-steel well casing or from riveted casing.

Concrete screens combine the functions of a casing with those of a screen, in that they can be made with ample strength to resist caving and yet provide a large infiltration area distributed in many small openings. Such screens are manufactured in pre-cast reinforced units, ranging from 7½ to 32 inches in outside diameter, which are assembled with steel rods or cables connecting the units and serving as reinforce-

ment. Screens of much larger size can also be cast at the well site. Concrete screens are of two general types, those which are porous or permeable throughout and those which are made of dense concrete that has very slight permeability of itself but are molded to provide inlet ports. The ingredients of the porous concrete screens are sand or fine gravel, which is carefully selected as to size and assortment of grains, and just enough cement to serve as a binder but not enough to fill all the interstices between sand grains. Another type consists of a cylindrical skeleton of dense reinforced concrete with longitudinal panels of permeable material.

In wells of large yield the entrance velocity of the water may be so great that the wells must be plugged at the bottom in order to prevent the rise of gravel, unless they extend to the underlying solid rock. Many screens, particularly those of the tubular type, are tightly closed at the bottom; screens which are open at the bottom may be closed with plugs of cement or wood after the screen is in place. Even though the bottom of the well is closed, however, some sand is likely to enter the perforations, and a part of it settles to the bottom of the well. If such sand is allowed to accumulate, occasional cleaning by sand pumping becomes necessary. According to Bryan[43] it has been found in the Sacramento Valley of California that wells ending in gravel may be closed at the bottom by perforated cement plugs which are pre-cast and lowered into place with a bail, and that the movement of water through the perforations keeps the sand in suspension so that it is drawn out in the ordinary course of pumping.

Methods of placing screens

Four methods of placing screens at the bottom of water wells are in general use—bailing down, using compressed air, washing down, and jacking back the casing. If a screen is to be placed by bailing down, an unperforated casing of diameter larger than the screen may be put down to the top of the water-bearing bed by any convenient method, and the screen is then run into the hole at the end of a string of temporary casing. The loose sand and gravel is then removed with a bailer or sand pump through the screen, which will sink of its own weight as long as the loose material outside moves freely downward and inward into the cavity created by the bailing. In some shallow wells the outer casing can be dispensed with, and the screen can be attached at the lower end of the permanent casing and bailed down from the surface. Obviously this method can not be used with screens which are closed at the end.

In placing a screen with the use of compressed air, the procedure is the same as in bailing down except that the loose material is removed from within the casing with an air-lift pump. This method has a distinct advantage in that the well may be "back blown" periodically by forcing water into the well under pressure of the compressed air, so as to stir up the material and facilitate penetration. Also, it is particularly suited to setting screens which are closed at the bottom, but it may not be successful in coarse materials.

If the well is being drilled by the rotary hydraulic method, the

[43] Bryan, Kirk, Geology and ground water resources of Sacramento Valley, California: U. S. Geol. Survey Water-Supply Paper 495, pp. 115, 117, 1923.

screen may be washed in with jetting tools, although this method is usually considered inadvisable.

With each of these three methods of setting screens, it is highly desirable that the thickness of the water-bearing bed and the size of the particles of sand or gravel be known from a test hole in order that a screen of suitable mesh, diameter, and length may be selected.

In many ways the most satisfactory method of placing a screen is by jacking back the casing. An unperforated casing larger than the screen is first put down through the water-bearing bed, the screen is placed at the bottom of the hole, and the outer casing is pulled back with jacks so as to expose the water-bearing material. By this method the texture and thickness of the water-bearing material are determined in the well itself rather than in a test hole, and any type of screen can be set successfully.

When a screen is set by jacking back the outer casing, it is impossible to seal that casing in place with cement or clay in order to shut out water of undesirable quality. Before the screen is set by any method other than jacking back, however, the outer casing can be sunk only to the top of the water-bearing bed and then sealed in place. After the screen has been set, by whatever method, the temporary inner casing, if used, can be cut off at the top of the screen and sealed to the outer casing with a packer if desired.

Gravel-wall wells

In unconsolidated deposits it is generally possible to increase the effective diameter of a well screen materially by building up a mantle of clean coarse gravel outside of the screen. This is feasible with any of the metallic screens and methods of placing them. By this process the entrance velocity of the water is reduced and the likelihood that the strainer will become clogged with fine sand is lessened. Indeed, if a large well is desired the success of the well will probably depend upon the thoroughness with which such a gravel mantle is built up.

If the water-bearing material is a mixture of sand and gravel, like much of the glacial outwash and alluvium in southwestern Pennsylvania, a natural gravel-wall well can usually be developed readily. Under such conditions the openings in the screen should be large enough to admit all but the coarser particles, and the gravel wall should be developed by alternately pumping and back blowing with compressed air, by "rawhiding" with a pump, by swabbing, or by bailing. In using compressed air, the well is equipped with an air-lift pump so constructed that the air pressure may be reversed at the will of the operator and water drawn from the well or forced down into the water-bearing stratum. When water is forced down into the well, the sand and gravel near the well are strongly agitated, and the fine particles are thrown into suspension. If then the well is pumped, many of the fine particles are drawn through the screen and discharged. These operations should be carried out gently at first, then gradually increased in vigor and continued as long as any sand can be drawn into the well. After a proper gravel mantle has been developed it can be kept free from accretion of fine particles by back blowing and cleaning the well periodically. A gravel mantle can also be produced by "rawhiding." In this method the well is first pumped rapidly in

order to stir up the water-bearing formation about the screen and then slowly until all the loose sand grains have been drawn into the well. This cycle of operation is repeated time after time, and the periods of rapid pumping are gradually lengthened until the well can be pumped continuously at its full capacity without discharging sand. The method of developing a gravel wall by swabbing or bailing needs no explanation; the operations are carried on as long as sand can be removed from the well.

If the water-bearing bed is overlain by soft material, the removal of a large quantity of fine sand from around the well might induce caving, with the possible result that the casing would be crushed. Under such conditions the fine sand removed should be replaced with an equivalent volume of coarser material, as in the construction of an artificial gravel-wall well.

In a water-bearing bed composed wholly of fine sand an artificial gravel mantle can be obtained by introducing sized gravel into the hole.[44] This operation may be carried out with any of the methods for setting screens, but is especially well adapted to the method of jacking back the outer casing. After the screen has been seated firmly at the bottom of the hole in this method, the annular space between the screen and the outer casing is filled with clean, well-assorted gravel of wheat to pea size. The outer casing is then jacked back slowly to the top of the water-bearing bed as the well is pumped and back blown or "rawhided." As fine material is pumped from the well and the gravel settles in the annular space, more gravel is added until a stable condition is reached. Unless the inner casing is too small to admit a pump of the desired size, both casings should extend to the surface of the ground, and the annular space between used as a reservoir of clean gravel to replace that which settles in the well in course of time. If the screen is placed by bailing or washing down or with compressed air, the clean gravel is poured in between the outer and inner casing as the screen is carried down, and more is added as the well is developed. In a few places gravel has been introduced into the water-bearing bed through auxiliary holes drilled several feet away from the well.

PUMPING PROBLEMS

Fundamental principles

The choice of the type and capacity of pump best suited to a particular well is dependent upon the behavior of the well under draft, an understanding of the hydraulic principles and definitions involved being essential. Meinzer[45], has given these definite expression as follows:

"The **drawdown** of a well from which water is being discharged at a given rate is the lowering of the water-level or the equivalent reduction in the pressure of the water in the well caused by the withdrawal of water. In a well that discharges by artesian pressure the reduction in pressure

[44] Hall, C. W., Meinzer, O. E., and Fuller, M. L., Geology and underground waters of southern Minnesota: U. S. Geol. Survey Water-Supply Paper 256, pp. 86-87, 1911. Meinzer, O. E., Finishing wells in sand: U. S. Geol. Survey Water-Supply Paper 293, pp. 190-195, 1912. Meinzer, O. E., and Hare, R. F., Geology and water resources of Tularosa Basin, New Mexico: U. S. Geol. Survey Water-Supply Paper 343, pp. 120-122, 1915.

[45] Meinzer, O. E., Outline of ground-water hydrology, with definitions: U. S. Geol. Survey Water-Supply Paper 494, pp. 61-63, 1923.

can be measured by means of a pressure gage. In a well that is pumped by suction the reduction of pressure can be measured by a vacuum gage; this method is applicable especially if the casing is used as the suction pipe. The drawdown is generally expressed in feet or meters.

"When the well is at rest there is equilibrium between the pressure of water outside the well and the pressure of the water inside. The pressure on the inside may be reduced by lowering the water level, by removing the atmospheric pressure in a well pumped by suction, or by relieving the pressure at the mouth of a well that discharges by artesian pressure. When the pressure on the inside is reduced the equilibrium is destroyed, and there is a resultant inward pressure, in consequence of which water flows into a well. It is obvious, therefore, that drawdown is invariably present when a well is yielding water.

"The **area of influence** of a well from which water is being discharged at a given rate is the land area that has the same horizontal extent as the part of the water table or other piezometric surface that is perceptibly lowered by the withdrawal of the water. The area of influence for a given rate of discharge may vary with the period of withdrawal and with the rate of recharge.

"The **cone of influence** of a well from which water is being discharged at a given rate is the depression produced in the water table or other piezometric surface by the withdrawal of the water. If the aquifer is nearly uniform in shape and texture in the vicinity of the well this depression has somewhat the form of an inverted cone whose apex is at the water level in the well while discharge is in progress, whose height is equal to the drawdown, and whose base is the original water table or other piezometric surface within the area of influence.

"The discharge of a well is almost invariably produced either by artesian pressure or by the operation of a pump or other lifting device. The term **artesian discharge** is used to designate the process of discharge from a well by artesian pressure, and also the quantity of water thus discharged. In some wells the artesian pressure is aided by the buoyancy of natural gas that enters the well with the water. The term **pumpage** is used to designate the quantity of water withdrawn from a well by means of a pump.

"The **capacity** of a well is the rate at which it will yield water. It can be expressed in gallons per minute, in second-feet (cubic feet per second), or in other units. Four kinds of capacity are recognized—total capacity, tested capacity, artesian capacity, and specific capacity.

"The **total capacity** of a well is the maximum rate at which it will yield water by pumping after the water stored in the well has been removed. It is the rate of yield when the water level in the well is drawn down to the intake.

"The **tested capacity** of a well is the maximum rate at which it is known to have yielded water without appreciable increase in drawdown. If the well has been tested with the water level drawn down to the intake—that is, by pumping all that the well will yield—the tested capacity is the total capacity. It is, however, seldom practicable to pump a well of large capacity at a sufficiently rapid rate to draw its water level down to its intake.

"The **artesian capacity** of a well is the rate at which it will yield water at the surface as a result of artesian pressure.

"The **specific capacity** of a well is its rate of yield per unit of drawdown. The term is applied only to wells in which the drawdown varies approximately as the yield. In such wells the specific capacity can be estimated by dividing the tested capacity by the drawdown during the test. Thus, if in such a well the yield is 250 gallons a minute and the drawdown is 10 feet, the specific capacity can be stated as 25 gallons a minute for each foot of drawdown, or if the units involved are known, it is sufficient to say that the specific capacity is 25.

"A well will always yield water at a greater rate immediately after a period of rest than after there has been continuous discharge for some time. This increase in yield is due to the accumulation of water in or near the well during the period of rest. After the accumulated water has been disposed of, the rate at which water enters the well is nearly equal to the rate at which it is discharged (provided the forces that produce

discharge remain uniform), although there may be a small persistent difference that will result in a gradual decrease or increase in capacity. Therefore, any accurate statement of capacity must be based on observations made after both the rate of discharge and the drawdown have become nearly constant. Moreover, on account of the gradual changes that may be developed by protracted discharge, the statement, to be entirely reliable, must give the results of several observations made at stated intervals during a considerable period of relatively stable conditions.

"**Interference** of two or more wells occurs when their cones of influence come into contact with one another, thereby decreasing the specific capacities of the wells."

Careful determination of the yield and drawdown of each new well should be a routine part of the driller's work, so that its ability to meet the intended draft may be accurately known. This is especially important in southwestern Pennsylvania, where few of the rocks yield water copiously, and the draft upon many wells must be as large as possible. Obviously, the rate of draft can not long exceed the rate at which water enters the well when the water level is drawn down below the water-bearing bed. However, the rate at which water enters many wells is much less than the capacity of the pump, which is therefore operated intermittently for short periods and draws largely upon water stored in the well.

The *theoretical head* against which a pump operates is the distance measured vertically, from the water level in the well while the pump is in operation to the point at which the water is discharged; it consists of the suction head and the discharge head. The *suction head* is the vertical distance from the pump downward to the water level while the pump is in operation. If the pump is below the water level the suction head is negative; otherwise the suction head is positive. The *discharge head* is the vertical distance from the pump upward to the point of discharge. Actually, however, the pressure against which a pump operates is somewhat larger, the difference consisting of friction loss within the pipes, or *friction head*, and the head which is equivalent to the kinetic energy of the moving water column, or the *velocity head*. The sum of suction head, discharge head, friction head, and velocity head is often called the *total head,* although that term is loosely used. Head may be expressed in feet of water, in the equivalent pressure in pounds per square inch, or in other units.

The quantity of water actually raised by a pump with a certain power input, is somewhat less than that which it is theoretically possible to raise, the difference being due to dissipation of energy within the pump. The ratio of the actual yield to the theoretical yield is usually expressed as a percentage and is termed the efficiency of the pump. The efficiency of pumps varies greatly among different types, and for anyone type it varies with the suction head, the discharge head, and the capacity and mechanical condition of the pump. The efficiency of the pump being disregarded, the power required to pump water at a particular rate varies directly as the total head. Conversely, for a particular pump and amount of power, the theoretical yield varies inversely as the total head.

The larger dealers in pumping equipment maintain technical service departments whose function it is to specify the type and size of pump best adapted to a particular well. Recourse to these departments would avoid poor choice of equipment and costly operation.

Types and Capacities of Pumps

RECIPROCATING PUMPS

The most common type of pump used in wells drilled in the consolidated sediments of southwestern Pennsylvania is the deep-well force pump. In its simplest form the cylinder of such a pump is a vertical tube, which is fitted at the bottom with a check valve that permits water to flow upward and in which is a plunger with a check valve that also permits water to flow only upward. The cylinder is suspended in the well at the lower end of a string of pump pipe or drop pipe, which carries the water to the surface. The plunger is actuated by a so-called pump rod or sucker rod of wood, solid metal, or pipe, that extends downward through the pump pipe. As the simple form described, the single-acting cylinder, delivers water only on the upward stroke of the plunger, its action is intermittent. A double-acting cylinder is so constructed that it delivers water on both the upward and the downward strokes. Both single and double acting pumps are made under a number of patents and vary widely in type and setting of valves as well as in other details.

Many styles, especially in the larger sizes, are so constructed that the plunger and the lower valve may be unscrewed and removed from the well without disturbing the pump pipe. Deep-well force-pumps if kept in good condition have rather high efficiency, but as the plunger and valves become worn the efficiency may decrease greatly, so that considerable expense for upkeep may be unavoidable. Single-acting cylinders may be placed at any desired depth below the surface, but the wear and tear on parts becomes much greater as the weight of the pump rods increases, and the efficiency decreases as the total head becomes very great. Double-acting cylinders may, on account of mechanical limitations, be less successful if set far below the surface. Cylinders are manufactured in many sizes ranging from those used on hand-operated pumps, which have capacities of 3 gallons a minute or less, to those which yield several hundred gallons a minute. Deep-well pumps may be operated by ordinary pump handles, windmills, or pump jacks. A pump jack is essentially a crank shaft whose motion is transmitted through a connecting rod to a crosshead attached to the upper end of the pump rod. The crank shaft is driven through suitable gearing by a direct-connected electric motor or by a belt or chain connected motor or gas engine. A deep-well pump may also be driven by a single-cylinder vertical steam engine directly connected to the upper end of the pump rod, but devices of this type are passing out of use. A group of wells equipped with deep-well pumps may be actuated as a unit from a central source of power through radiating jerk lines or rods leading to pump jacks of the well-known Pennsylvania oil-field type. An especially rugged type of such a pump jack is shown in Figure 11.

Wherever the water level is sufficiently close to the surface, piston displacement pumps of one, two, or three cylinders are frequently used. The motive power may be steam, natural gas, or electricity. Such pumps are made in many styles and in any desired capacity. Their efficiency decreases notably as the suction head is increased toward the maximum attainable, which is theoretically about 34 feet.

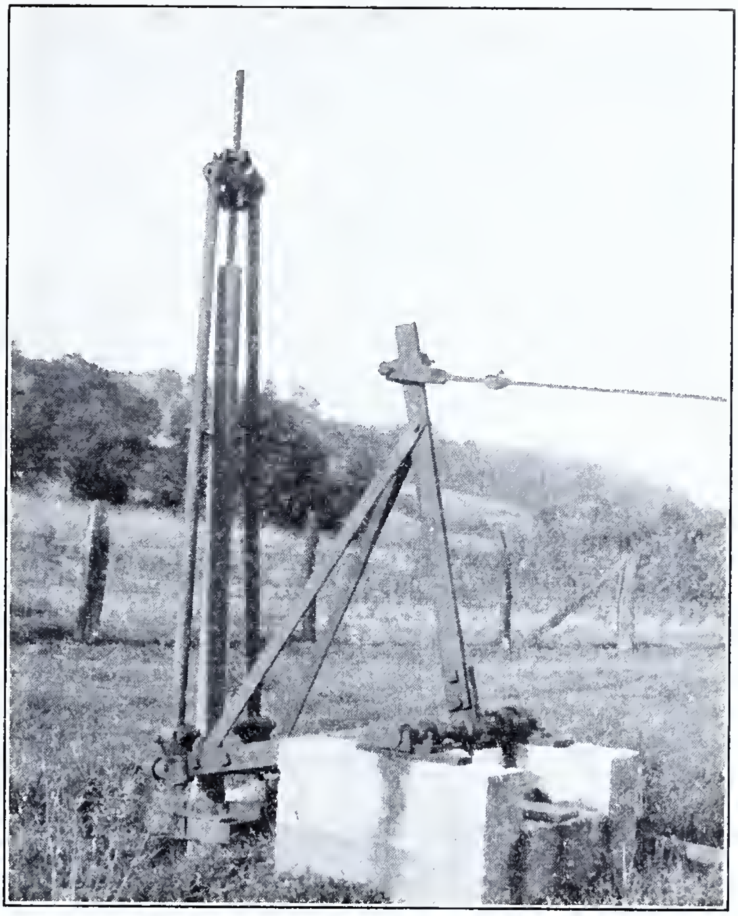

Figure 11. Rod-actuated pump jack of the Pennsylvania oil-field type as installed on Evansburg Borough municipal wells, southwestern Butler County.

In practice, however, it is not usually possible to increase the suction lift beyond 28 feet, and the efficiency is low whenever it is more than 25 feet. Consequently such pumps should be so installed that the suction lift is low.

AIR LIFTS

In southwestern Pennsylvania air lifts are used in many deep wells of large capacity. An air lift consists of an eduction pipe which extends far below the water level and an air pipe which carries compressed air to the eduction pipe near its lower end (fig. 12). The performance of an air lift depends upon many factors, such as the size, arrangement, and submergence of the eduction and air pipes and the quantity of air supplied.

Two styles of air-lift pumps are common—those with outside air pipe and with central air pipe. In the style with outside air pipe, which is illustrated in Figure 12, the eduction and air pipes are suspended in the well side by side and join near the base in a foot piece, whose function is to allow the air to pass smoothly into the water in as small jets as possible. Although many complex types of foot pieces

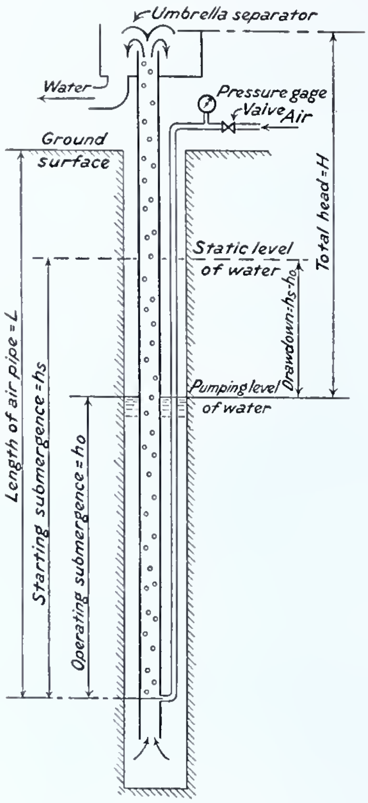

Figure 12.—Air lift installed in deep well.

are manufactured under patent, it has been shown by Ward[46] that any device which allows the air to pass freely into the water and gives unobstructed passage for the water is quite as efficient as the most complex. He shows further that great refinement of design is not essential and that nozzles and projecting parts which obstruct the flow of water are undesirable. In the style with central air pipe, the air pipe is placed within the eduction pipe and may or may not terminate in a nozzle that contains a number of small air ports. The central air pipe reduces the efficiency somewhat but allows a larger eduction pipe to be placed in the well.

For a stated discharge, the quantity of air required and consequently the diameter of the air pipe vary with the lift and also with the percentage of submergence. If, for the stated quantity of air, the eduction pipe is too large there is great slippage of air through the water; if, on the other hand, the eduction pipe is too small, the velocity of the fluid column and consequently the friction head are increased. The diameters specified by a well-known manufacturer are shown by the following table:

[46] Ward, C. N., Experimental study of air-lift pumps and application of results to design: Wisconsin Univ. Bull., Eng. ser., vol. 9, No. 4, serial No. 1265, pp. 30, 55-65, 1924.

Diameters of eduction and air pipes for air lifts of specified capacities.

Outside air pipe				Central air pipe		
Capacity (gallons per minute)	Diameter of eduction pipe (inches)	Diameter of air pipe (inches)	Diameter of smallest well admitting installation (inches)	Capacity (gallons per minute)	Diameter of eduction pipe (inches)	Diameter of air pipe (inches)
20	1½	½	4	15–30	1½	⅜
50	2	¾	4	30–50	2	½
75	2½	1	6	50–70	2½	¾
100–150	3	1¼	6	70–100	3	1
150–200	3½	1¼	8	100–150	3½	1
200–300	4	1½	8	150–200	4	1¼
300–350	4½	1½	8	200–250	4½	1¼
350–500	5	2	10	250–300	5	1½
				300–450	6	2
				450–600	7	2½

There are two kinds of submergence—starting submergence and operating submergence. Submergence is usually expressed in percentage by the formula:

$$\frac{100h}{h+H}$$

in which h = operating submergence = depth that air pipe is submerged during operation.

H = total head = depth of water level in well below point of discharge during operation.

This ratio is the most critical factor in the performance of the air lift, and if the maximum efficiency is to be attained it can not depart greatly from the quantities specified in the following table:

Desirable and permissible submergences for air lifts.

Total head (H) (feet)	Submergence ratio $\frac{100\ h}{h+H}$ (per cent)	
	Desirable for maximum efficiency	Permissible
20–35	65–70	55–70
35–85	65–70	50–70
100	65–70	45–70
125	65	45–65
150	60–65	40–65
175–250	55–60	40–60
300–350	50–55	37–55
400	45–50	37–50
450–500	40–45	35–45

It follows from the desirable submergence ratio that the drawdown and consequently the discharge that can be obtained by an air lift is limited by the depth of the well in proportion to the total pumping head. Drilling the well far below the water-bearing bed in order to gain the desirable submergence detracts somewhat from the efficiency, because of friction against the water column moving downward from the water-bearing bed and between the eduction pipe and the wall of the well.

The third principal factor in the performance of the air lift is the quantity of air admitted to the eduction pipe. If the quantity of air is small, the pump discharges "by heads," or intermittently. As the quantity of air is increased the discharge becomes continuous and increases until the condition of maximum efficiency—the largest discharge per compressor horsepower—is attained. As a still greater quantity of air is supplied the discharge of the pump increases with a declining efficiency at first; finally it fails to increase further even though the quantity of air is increased greatly. If the capacity of the air lift exceeds the rate at which water flows into the well, the discharge is also "by heads," or intermittent, as if the quantity of air supplied were insufficient.

Minor details of design that affect the friction losses in the air and eduction pipes are reflected directly in the efficiency of the unit. The connection from well to compressor and to discharge tank should be as short and as straight as possible, with the minimum of couplings, bends, and other fittings. The ends of the sections of pipe should butt against one another within each coupling. In the eduction pipe all bends should be of long radius, and long horizontal portions should be avoided. The type of eduction orifice is also important, the most approved arrangement being an open-ended vertical pipe which discharges against the so-called umbrella separator.

The performance of an air lift can be ascertained at any time if the length of the air pipe—measured vertically from the surface to the foot piece—is known, and if the air pipe is fitted with a valve and a pressure gage, which must be located between the valve and the well. The air pressure recorded by the gage is equivalent to a column of water equal in height to the submergence at the instant plus the friction loss in the air pipe and foot piece. Thompson[47] has found that the true starting pressure is the highest reading of the gage after the compressor is started and just before the sharp drop of the gage needle which indicates that air has passed out of the foot piece and into the eduction pipe. He has found further that the effect of friction in the air pipe may be canceled and the theoretical operating pressure may be determined accurately by closing the valve in the air line quickly and noting the lowest pressure recorded by the gage immediately thereafter. It is essential that the valve be closed quickly so that the motion of the air column is checked abruptly and that a gage reading be obtained before the velocity of water in the eduction pipe has decreased appreciably. Mathematically expressed:

$$\text{Starting submergence in feet} = h_s = 2.31\ P_s$$
$$\text{Operating submergence in feet} = h_o = 2.31\ P_o$$
$$\text{Drawdown} = h_s - h_o = 2.31\ (P_s - P_o)$$
$$\text{Depth to water} = L - 2.31\ P$$

in which P = theoretical air pressure at any instant, in pounds per square inch

P_s = starting air pressure, in pounds per square inch
P_o = operating air pressure, in pounds per square inch
L = length of air pipe, in feet, measured vertically from ground surface to foot piece

[47] Thompson, D. G., personal communication.

The principal advantages of the air-lift pump may be summed up as follows:

1. The first cost is low, and, owing to the absence of moving parts, the cost of upkeep is small.
2. It can be installed in a well which is not straight and will not admit a deep-well force pump or turbine centrifugal pump.
3. It is very reliable, inasmuch as none of its parts are subject to breakdown or to deterioration.
4. It is more flexible than most other pumping devices, being adequate to meet a 50 per cent overload. Moreover, several pumps can be run by one compressor with a minimum of duplicated parts.
5. Abrasion of the parts by sand and silt in the water is not of consequence.
6. Aeration of the water removes objectionable odors and induces the precipitation of dissolved iron and carbon dioxide.

The disadvantages of the air lift, even where it can be used, are the delicate balance of factors necessary to obtain maximum efficiency, the technical skill required to maintain that balance, and the low efficiency obtainable under many conditions. Although Ward[48] has shown that efficiencies of 50 to 60 per cent may be attained within the pump itself, the overall efficiency of the air-lift plant is reduced in proportion to the inefficiency of the compressor. Air compression is costly unless the power is a by-product of some other process. Under ideal conditions overall efficiencies are attainable which will compare favorably with those of mechanical pumping devices.

CENTRIFUGAL PUMPS

The various forms of centrifugal pumps are, within their mechanical limitations, well adapted to pumping the large quantities of ground water developed in the alluvial deposits of the principal valleys in this region. The motive power may be applied through a belt or by direct connection to an electric motor or other prime mover. The use of a belt incurs some loss of efficiency but possesses the advantage that the speed of the pump can be varied within relatively wide limits, the smaller sizes of pumps and those operated against the greater heads being run at higher speed. If the pump is connected directly, the motor should be designed to meet the particular conditions of operation. Most manufacturers of centrifugal pumps maintain technical service departments, and hence the burden of making a proper selection need not be assumed by the purchaser.

The turbine centrifugal or deep-well turbine pump has been little used in southwestern Pennsylvania, although it is well suited to many conditions in the area and is very widely used in other areas. Deep-well turbine pumps are made in sizes to enter well casings from 8 to 24 inches in diameter and have capacities ranging from 100 to 6,000 gallons per minute. The larger sizes may be placed in a cylindrical steel pit, which is sunk by ordinary well-drilling methods and, by means of suitable attachments, is made an integral part of the well casing. On account of the type of construction necessitated by the limitation in diameter, a single impeller will not operate against a total head of more than 20 or 30 feet, but the multistage types operate

[48] Ward, C. N., op. cit., pp. 52-62.

successfully against heads of several hundred feet. The pump is set at any desired depth in the well—preferably so that it operates with a negative or small positive suction head—and is suspended from a suitable head frame at ground level. Power is applied either through a belt or by a direct-connected vertical prime mover, usually an electric motor.

Deep-well turbines will develop the maximum capacity of the well if set as far as possible below the surface, although the resultant large drawdown increases the total head and, consequently, the cost of power and upkeep. They require little floor space, do not require priming if set below water level, and are oiled from the surface. However, it is usually desirable to erect a permanent derrick over any well equipped with such a pump, for inspection and repair necessitates hoisting the entire heavy unit from the well.

Small Water-Supply Systems

A type of water-supply system for suburban residences and villages which is growing in favor in southwestern Pennsylvania, as well as in other regions, consists of an automatically controlled deep-well force pump which discharges into a closed tank against the pressure of air trapped therein. As the pump forces water into the tank, the pneumatic pressure rises until it suffices to open a circuit breaker and to stop the electrically driven pump. A suitable water pressure is thus created in the piping system which leads from the tank near its base. As water is drawn from the service taps, the pressure falls until it attains a minimum which allows a motor starter to function automatically and to start the pump. A suitable air pump is provided for replacing the air that leaks from the tank or is taken into solution by the water. Such water-supply systems are made in a number of compact, rugged styles which give good satisfaction with little attention. Most of them range in capacity between 2 and 10 gallons a minute.

In selecting a unit of this type care should be taken lest the capacity of the pump exceed the total capacity of the well and lest the storage capacity of the tank be inadequate. It should be borne in mind that a well which can be pumped steadily at the rate of 1 gallon a minute will yield 1,440 gallons in 24 hours, a quantity which is several times the usual daily consumption of a single household. Even a well that will yield less than 1 gallon a minute, such as many wells in southwestern Pennsylvania, may furnish an ample quantity of water for a household supply if the tank is large enough. Notwithstanding some prejudice to the contrary, water does not suffer in palatability by standing several hours in a clean tank if its temperature remains moderate. Water-supply systems of this type would operate more economically and would have a longer life if the pump capacity were reduced to the minimum and the burden of equalizing a fluctuating draft were transferred from the well to the storage tank.

TEMPERATURE AND THERMAL GRADIENT

The temperature of ground water, a property of some importance for many industrial uses, is usually about the same as the tempera-

ture of the rock from which the water is derived and depends upon the depth of the source rock beneath the surface. The soil and rock which are exposed at the surface follow the daily and seasonal fluctuations in air temperature at that place. The fluctuations in earth temperature die out rapidly beneath the surface, however, the daily fluctuation affecting only a very thin layer of soil and the annual fluctuation being small at 10 feet below the surface and becoming zero at a depth of 30 to 60 feet. Van Orstrand has pointed out that under normal conditions the temperature of ground water at the base of this zone of seasonal fluctuation is generally 2° or 3° greater than the mean annual air temperature and that in exceptional localities it may be 5° or even 6° greater.[49] Below the zone of seasonal fluctuation the earth temperature increases with depth at a rate which varies somewhat from one district to another but does not differ greatly in any one district.

The mean annual temperature in southwestern Pennsylvania ranges from 50.2° to 52.6° F. at the several climatologic stations (see p. 10) and averages 51.5°. The average of ground-water temperatures observed in wells less than 100 feet deep and drilled into the consolidated rocks is 51.8°; in wells between 100 and 200 feet deep, 52.1°; and in wells from 200 to 450 feet deep, 52.5°. Water supplies obtained at any depth between 50 and 450 feet will have a temperature which is satisfactory for all ordinary uses. The ground water from unconsolidated deposits in the zone of seasonal fluctuation ranged from 52.5° to 56.5° in the autumn of 1926; temperatures as high as 60° were reported but not observed.

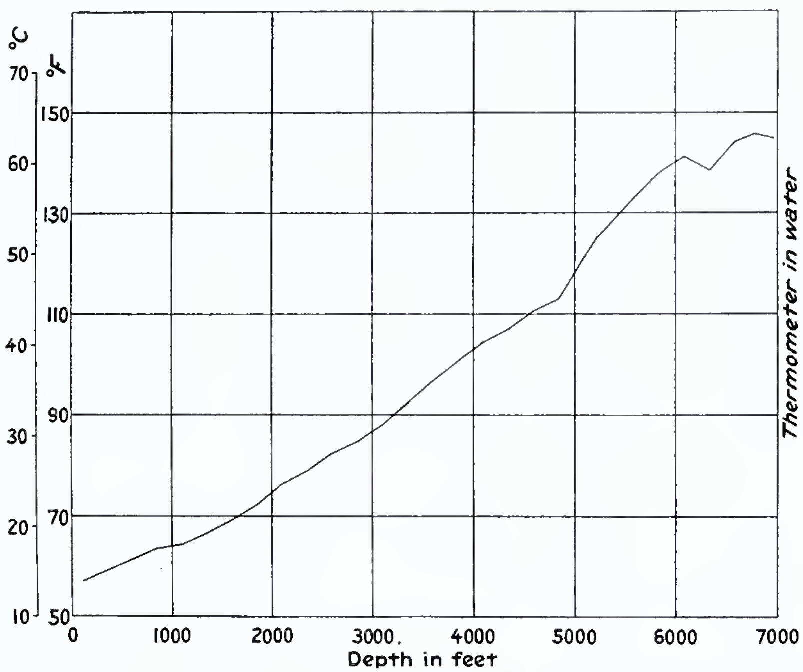

Figure 13. Depth-temperature curve of R. A. Geary well of Peoples Natural Gas Co., No. 1046, 2½ miles north of Midway, Washington County.

[49] Collins, W. D., Temperature of water available for industrial use in the United States: U. S. Geol. Survey Water-Supply Paper 520, p. 98, 1925.

The thermal gradient, or rate of increase of earth temperature with depth, for southwestern Pennsylvania is shown by Figure 13, based on earth temperatures observed by Van Orstrand.[50] The curve is slightly concave upward, the thermal gradient increasing steadily to a depth of approximately 6,000 feet beneath the surface. Between depths of 100 and 2,000 feet the temperature increases at an average rate of 1° for each 110 feet of depth; between 2,000 and 5,000 feet it increases at an average rate of 1° for each 95 feet of depth.

ARTESIAN CONDITIONS

Artesian conditions exist where a body of water within a permeable bed is inclosed by overlying and underlying impermeable beds under sufficient hydrostatic pressure to rise above the water table. The hydrostatic pressure is due to the weight of the water which saturates the permeable bed and its tributary channels to a level higher than that of the water-table of the artesian area. Flowing wells may be obtained in parts of an artesian basin where the pressure is sufficient to raise the water to the surface. In other parts the water may rise above the water table but not above the land surface. Other conditions being equal, the yield of a flowing well is proportional to the head measured at the surface. The essential factors controlling artesian conditions have been outlined by Chamberlin[51] and Fuller.[52]

Inasmuch as the greatest hydrostatic pressure within a bed exists along the axes of synclines, the localities where these axes form valleys are the most favorable localities for obtaining flowing wells. If the amplitude of the secondary folding is small, the artesian conditions are dependent on the primary structural feature only and may exist along secondary anticlines and synclines alike. If, however, the amplitude of the secondary folding is large, the artesian conditions are dependent upon the secondary rather than the primary structural features.

Wells that flow at the surface because of the hydrostatic pressure of the water exist in each of the six counties covered by this report. Other wells, drilled to the gas sands, have flowed for a time under the influence of natural gas mixed with the water of the permeable beds but have ceased to flow when the gas became depleted.

In the following table are listed the beds which are known to supply flowing wells in one or another part of the area, together with references to the pages on which those beds are described. All except the surficial rock waste are sandstones. The area of artesian flow for each embraces a number of small localities.

[50] Van Orstrand, C. E., Apparatus for the measurement of temperatures in deep wells and temperature determinations in some deep wells in Pennsylvania and West Virginia: West Virginia Geol. Survey, Barbour and Upshur counties, pp. lxvi-ciii, 1918.

[51] Chamberlin, T. C., The requisite and qualifying conditions of artesian wells: U. S. Geol. Survey Fifth Ann. Rept., pp. 125-173, 1885.

[52] Fuller, M. L., Summary of the controlling factors of artesian flows: U. S. Geol. Survey Bull. 319, 44 pp., 1908.

Stratigraphic divisions that yield flowing wells in Southwestern Pennsylvania

	Pages of this report
Surficial rock waste	
Washington formation on mountain footslopes:	
Waynesburg sandstone	141
Conemaugh formation:	
Connellsville sandstone	159
Morgantown sandstone	163
Saltsburg and Buffalo sandstones	170
Mahoning sandstone	178
Allegheny formation:	
Freeport sandstone	186
Worthington sandstone	187
Kittanning sandstone	189
Clarion(?) sandstone	191
Pottsville formation	193
Pocono formation:	
Burgoon sandstone	198
Murrysville sand	201

ARTESIAN CONDITIONS IN THE KANAWHA SECTION

In Butler County the sedimentary rocks constitute a monocline which dips gently toward the southwest and is modified by the Mount Nebo and Bradys Bend synclines, open secondary folds whose axes strike N. 25°-60° E. (See Pl. 1). This structure constitutes essentially an artesian slope which yields flowing wells from the Pottsville and Burgoon sandstones. Typical among these are wells 105 and 108 of Marion Township* (Fig. 36), No. 109 of Venango Township; No. 126 of Slippery Rock Township, No. 127 of Cherry Township, No. 143 of Concord Township, and No. 157 of Donegal Township. Well 197 of Jefferson Township is doubtfully ascribed to this same group. In none of these wells is the static level of the artesian water more than twenty feet above the top of the well. The estimated discharges range from 5 to 175 gallons per minute. The fragmentary data available indicate that the piezometric surface[53] slopes southward or southwestward about 6½ feet to the mile, essentially parallel to the grades of the principal drainageways. Hence large artesian pressures are not to be expected. The area of artesian flow includes the valley of Slippery Rock Creek and its larger tributaries below the 1,210-foot surface contour—that is, westward from the meridian passing through the city of Butler; also the valley of Connoquenessing Creek and its larger branches (Bonnie Brook, Coal Run, and Thorn Creek) southward from the vicinity of well 143 to the latitude of Saxonburg and westward to the boundary of the county; also the bed of Buffalo Run eastward and southward from the vicinity of well 157 for an unknown distance. Whether the area of artesian flow embraces also any portion of the Allegheny Valley is uncertain. Throughout most of this district the Pottsville and Burgoon sandstones form essentially a single lithologic unit, and the water in the two sandstones is under nearly the same pressure head.

* For data on these and other wells referred to by number see tables under county descriptions in latter part of book.

[53] The piezometric surface of an artesian formation is the imaginary surface to which the artesian water will rise under its full head. (See Water-Supply Paper 294, p. 38, 1923.)

In the southern part of the province, in central Greene County, there are two wells which flow or have flowed by artesian pressure and are probably supplied by the Waynesburg sandstone although exact correlation of the water-bearing stratum is not possible. These are well 1078 of Center Township (Fig. 38) and well 532 of Franklin Township. Well 1078 is reported to have found water in sandstone, probably the Waynesburg, at a depth of 200 feet and to have flowed by artesian pressure before the sandstone was cased off. This well is in the valley of South Fork of Tenmile Creek, at the south end of the axis of the Amity anticline (Pl. I), a fold that plunges notably southward. The artesian pressure was not measured when the well was drilled but was probably not great enough to raise the water more than a few tens of feet above the surface. Well 532 is in the valley of Smith Creek on the west flank of the southward-plunging Bellevernon anticline, about 3 miles south of Waynesburg. The flow in October, 1926, was at least 25 gallons a minute (see Fig. 14),

Figure 14. Flowing well 532, 3 miles south of Waynesburg, Greene County. The flow comes from the Waynesburg sandstone of the Washington formation.

with considerable leakage outside the casing. It is also reported that the yield has not declined noticeably during the 12-year life of the well. The static level is probably not more than 10 feet above the surface. Inasmuch as the static level of water in the Waynesburg

sandstone is about 30 feet above the level of the creek bed at Waynesburg, the area of artesian flow is probably limited to the valley floors of South Fork between Waynesburg and Rogersville and of Smith Creek for not more than 4 miles southward from Waynesburg. Possibly also the valley of Ruff Creek, to the north, would yield flowing wells in the vicinity of the axis of the Waynesburg syncline (Pl. I).

It is seemingly anomalous that the only flowing wells of this district should occur along the axes of the anticlinal folds. However, these folds plunge southwestward about ½°, and those which yield flowing wells bring the coarse-grained permeable facies of the Waynesburg sandstone to the surface to create a zone of recharge toward the north. Hence, the anticlinal axes serve as artesian slopes. No wells of sufficient depth to reach the stratum have been drilled in the deepest part of the Waynesburg syncline, which passes midway between the two flowing wells.

Farther east, in northwestern Westmoreland County, well 423 of Franklin Township (Fig. 40) indicates artesian conditions in the upper two-thirds of the Allegheny formation, though the specific water-bearing member is unknown. This well is in the valley of Turtle Creek, midway between the axes of the Murrysville anticline and the Port Royal-Elders Ridge syncline. The artesian head and the hydraulic gradient, or slope of the piezometric surface, are not known; hence the area of flow can not be bounded with precision, although it probably extends for some distance along the creek bed between Export and Murrysville. The large content of dissolved iron renders the water unfit for many purposes, however, so that any projected development of this source should contemplate aeration as a means of improving the quality.

Except in the small areas of artesian flow outlined in the preceding paragraphs, artesian conditions do not exist commonly in the Kanawha section of the Appalachian Plateaus. Locally, however, flowing wells occur along the flanks of anticlinal folds whose axes have been trenched by erosion so that the water-bearing bed has been exposed; also along the axes of gently plunging anticlines which act as artesian slopes. Some flowing wells are difficult to explain. Certain of these wells may be due to the abrupt termination of a water-bearing bed in the flank of the fold below the well site; others, which occur at the axes of anticlines, may owe their existence to tension cracks in the strata that overlie the water-bearing beds, the creviced strata serving as reservoirs to establish a hydrostatic head. At these anticlinal wells the water-bearing member is less than 75 feet below the surface, the static level is not more than 3 feet above the surface, and the flow ranges from only a fraction of a gallon to 5 gallons a minute. In each place the inclination of the piezometric surface is unknown, so that the extent of the area of artesian flow is problematic though probably small.

Among these fortuitous flowing wells are No. 216 of Adams Township (Fig. 36) and No. 218 of Middlesex Township, in the southwestern corner of Butler County, also No. 231 of Pine Township, in the contiguous portion of Allegheny County. These wells tap the Saltsburg and Mahoning sandstones, which rise northward and crop out in adjacent creek valleys within 5 miles of the wells. In southeastern Butler County well 204 of Winfield Township flows slightly by

artesian pressure. This well is on the axis of the Kellersburg anticline (Pl. I). In northwestern Washington County well 360 of Union Township encountered water under very low artesian head in the Connellsville sandstone half a mile east of the axis of the Amity anticline. The axis of this fold is essentially horizontal, so that the water-bearing bed does not crop out in the vicinity of the well site, and tension cracks along the axis seem to be indicated as a probable reservoir to establish artesian head. In eastern Allegheny County well 290 of Penn Township is reported to have established artesian pressure in the Saltsburg sandstone, although the well has since been abandoned, so that the report could not be verified. Well 291, half a mile to the southwest, passed through the same water-bearing bed and found it to be impermeable. Hence the artesian conditions seem to depend upon the termination of a permeable facies of the Saltsburg sandstone below the site of well 290.

Similar artesian conditions undoubtedly exist in other localities of the district.

ARTESIAN CONDITIONS IN THE ALLEGHENY MOUNTAINS SECTION

Water is confined under artesian pressure in many of the permeable sandstone strata of the Uniontown-Latrobe syncline (Pl. I). Typical flowing wells that tap beds of the Conemaugh formation along the axis and flanks of this trough are No. 472 of Unity Township, Westmoreland County; No. 617 of Georges Township, Fayette County; Nos. 496, 497, and 498 of Mount Pleasant Township, Westmoreland County; and No. 607 of North Union Township, Fayette County. The natural flow from these wells ranges from a mere trickle to 200 gallons a minute. A critical factor in the existence of artesian conditions in the Conemaugh formation is the discontinuity of permeable zones within its sandstone beds, a condition which destroys the continuity of the piezometric surface and makes it impossible to delineate the areas of artesian flow. In general, the piezometric surfaces for these beds seem to slope toward the axis of the valley with gradients that are but little less than the inclination of the land surface so that wells with large artesian pressure and flow are not to be expected. Flowing wells should be obtainable rather generally, however, along the axis and lower flanks of the trough wherever permeable beds exist and the streams have cut below the 1,200-foot contour in Westmoreland County or below the 1,150-foot contour in Fayette County. In the deepest part of the trough the beds yield highly concentrated brines, which were formerly recovered as a source of salt in the vicinity of Latrobe.

The base of the Freeport sandstone of the underlying Allegheny formation supplies flowing wells of small yield on the flank of the trough and about 350 feet above the floor of the valley at site 440 of Derry Township, Westmoreland County. The water-bearing bed crops out about half a mile to the east. This may indicate a rapid decrease in permeability of the stratum toward the west, so that an artesian head is maintained in the vicinity of the outcrop. Although flowing wells from the Allegheny formation are not known elsewhere in the Uniontown-Latrobe syncline, potential artesian conditions exist in permeable facies of the sandstone members in the deeper part of the fold.

In the same trough the sandstones of the Pottsville formation supply flowing well 422 of Derry Township, Westmoreland County (Fig. 40). The static level is about 12 feet above the surface, and in October, 1926, the estimated flow was 150 gallons a minute. So far as is known, no other wells tap the formation in this vicinity, and the static level at other places is not known. In view of the relatively uniform texture of the sandstones of the Pottsville formation throughout the region of the outcrop, however, the discontinuity of permeable zones is not a vital factor in the existence of artesian conditions. The Pottsville formation is, therefore, of greater promise as a source of flowing wells than any of the overlying formations, although in the deepest part of the trough it probably contains only saline water.

Farther east, in the Ligonier syncline, well 445 of Fairfield Township, Westmoreland County (Fig. 40), flowed by artesian pressure from the Butler sandstone of the Allegheny formation and the Burgoon and underlying sandstone members of the Pocono formation. The main yield was obtained from the Burgoon sandstone at a depth of 1,200 feet. The static level of the water is reported to have been at least 20 feet above the surface when the well was drilled, in 1918. The estimated flow during October, 1926, was 35 gallons a minute, although the mouth of the well was caved and the water was escaping into the near-by creek through a crevice in the rock some 10 feet below the original casing head. No other wells reach these beds within the trough. In the southward extension of this basin, which is the Ohiopyle syncline, several shallow flowing wells tap the sandstone members of the Allegheny formation. Of these, No. 591 of Springfield Township, Fayette County is typical. The static level is only 2 or 3 feet above the surface in these wells, and the flow is not more than 3 gallons a minute. Undoubtedly these beds and several others will yield flowing wells in many of the lower parts of the valley floor, but it is not practicable to outline the areas of artesian flow.

Flowing wells less than 50 feet deep are found at several localities where erosion has exposed a tilted slightly permeable bed along the flank of a fold or where the rocks are jointed. Under the first condition the slight permeability of the bed beneath deep cover maintains an artesian head close to the outcrop. Under the second condition the joint planes serve as a reservoir which creates an artesian head where a permeable bed is tightly covered. Typical examples are well 465 of Hempfield Township (Fig. 40) and well 469 of Unity Township, Westmoreland County. These wells are on the west flank of the Fayette anticline (Pl. I) and the west flank of the Latrobe syncline, respectively. All such wells, however, have a very low pressure head and a small flow.

The surficial rock waste also yields flowing wells at several scattered localities in the Allegheny Mountains. Well 611 of South Union Township, Fayette County, is typical. These wells penetrate a variable thickness of clayey hill wash and find water either in coarse débris that locally constitutes the basal portion of the rock waste or in the weathered uppermost portion of the underlying solid rock. The permeability of the water-bearing material is low and variable, as is also the head. Hence the wells differ widely in flow. None yield copiously, the flow usually ranging from a mere trickle to about 1 gallon a minute. Furthermore, the head is subject to seasonal fluctuation, and in a few wells the flow is intermittent.

CHEMICAL CHARACTER OF GROUND WATER IN SOUTHWESTERN PENNSYLVANIA.

Analyses of representative waters.

(Margaret D. Foster and C. S. Howard, analysts, U. S. Geological Survey, Quantities in parts per million.)

No. on Figs. 35–40	Description	Temperature (°F.)	Analyst	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate radicle (HCO_3)	Sulphate radicle (SO_4)	Chloride radicle (Cl)	Nitrate radicle (NO_3)	Total dissolved solids at 180°C	Loss on ignition	Total hardness as $CaCO_3$[a]	No. on Figs. 35–40
	Waters from unconsolidated deposits.																
1	Harrisville, Butler County. Dug well 14 feet deep; water from glacial outwash gravel from 12 to 14 feet deep; owned by Cathcart Hotel	54	H	3.4	0.24	42	7.5	80	4.0	23	53	145	27	397	3.6	136	1
4	Sewickley, Allegheny County, 1 mile northwest of. Gang of four drilled wells 10 and 12 inches in diameter and 35 feet deep; water from alluvium; owned by Edgeworth Water Co.	56.5	H	8.8	.16	81	7.9	14	3.8	171	91	20	0.82	333	10	235	4
5	Springdale, Allegheny County. Drilled well 12 inches in diameter and 67 feet deep; water from alluvium; owned by Springdale Borough	53.5	H	12	.16	117	14	30	4.5	278	104	35	5.8	485	10	350	5
6	McKees Rocks, Allegheny County, 1½ miles north of. Gang of 28 drilled wells in main channel of Ohio River, each 12 inches in diameter and 35 to 45 feet deep; water from alluvium; owned by Ohio Valley Water Co.	------	H	7.2	.15	42	7.1	16	1.3	90	77	10	Trace	216	6.0	134	6
7	McKees Rocks, Allegheny County, 1½ miles north of. Gang of 16 drilled wells in back channel of Ohio River, each 12 inches in diameter and 35 to 45 feet deep; water from alluvium; owned by Ohio Valley Water Co.	------	[b]H	------	.17	76	10	[a]16		142	120	17	.49	------	------	231	7
17	Hendersonville, Washington County, 2 miles northwest of. Drilled well 5⅝ inches in diameter and 28 feet deep; water from alluvium; owned by Sam Deblasoi	52.5	F	16	.07	5.3	3.9	141	3.2	[c]388	5.0	12	1.1	382	3.0	29	17

21	Arnold, Westmoreland County. Drilled well 18 inches in diameter and 85 feet deep; water from alluvium; owned by United States Aluminum Co.	56	F	9.8	d108	51	13	22	1.8	43	119	44	.0	299	8.0	181	21
24	Mapletown, Greene County. Dug well 30 inches in diameter and 26 feet deep; water from sand of Carmichaels formation; owned by H. J. Williamson	54	F	10	.07	18	16	20	4.0	4.4	71	18	65	214	16	111	24
25	**Mcleroft, Fayette County, 1¾ miles southwest of (Davistown community).** Dug well 26 feet deep; water from alluvium; owned by Sam Kalp	56	F	4.3	.19	14	3.0	5.1	2.2	27	20	4.0	18	83	3.0	47	25
	Surface Water [Inserted for comparison]																
A	Colfax, Allegheny County, ½ mile west of. Untreated water from Allegheny River; sample taken from condenser circulation pump, No. 2 main unit of Colfax power station, Duquesne Light Co.	------	H	------	Trace	16	3.3		a5.0	27	30	7.4	.66	76	------	54	A
B	Connellsville, Fayette County, 2.7 miles south of. Untreated water from Youghiogheny River, sample taken at Trotter Water Co's intake on west bank	------	F	5.0	.07	6.9	2.4	1.3	.8	2.4	23	1.1	1.4	43	2.0	27	B
C	Sewickley, Allegheny County. Untreated water from Ohio River; sample taken opposite Sewickley municipal pumping station on north bank	------	H	5.9	.13	17	4.2	6.8	2.7	16	45	10	Trace	103	2.7	60	C
	Water from the consolidated rocks.																
	Butler County																
101	**Forestville, ½ mile north of.** Drilled well 6 inches in diameter and 85 feet deep; water from Vanport limestone from 50 to 70 feet below surface; at Harrisville station, Bessemer & Lake Erie R. R.	50	H	9.0	.37	87	9.1	3.5	2.2	264	40	2.2	Trace	279	1.6	255	101
103	Harrisville, 1¾ miles north of. Drilled well 6 inches in diameter and 30 feet deep; water from Middle Kittanning coal; owned by Harry Greene	49	H	12	d13	6.5	8.4	4.4	2.6	46	18	2.0	Trace	67	0.6	51	103

a Calculated.
b Approximate analysis only.
c Includes equivalent of 14 parts of carbonate (CO_3).
d Includes iron precipitated at time of analysis.

Analyses of representative waters—Continued.

No. on Figs. 35–36	Description	Temperature (°F.)	Analyst	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate radicle (HCO_3)	Sulphate radicle (SO_4)	Chloride radicle (Cl)	Nitrate radicle (NO_3)	Total dissolved solids at 180°C	Loss on ignition	Total hardness as $CaCO_3$[a]	No. on Figs. 35–36
105	Boyers, ¾ mile west of. Drilled well 6 inches in diameter and 100 feet deep; water from Homewood sandstone; at laborer's dwellings; owned by Pittsburgh Limestone Co.	50	H	7.1	.20	19	4.0	66	2.7	178	2.3	50	Trace	237	2.7	64	105
108	Boyers, ½ mile north of. Abandoned oil well plugged about 250 feet below surface; water from Burgoon sandstone; owned by Henry Middendorf	50	H	6.6	[d]7.1	59	14	45	6.7	112	178	28	Trace	390	8.6	205	108
154	Butler, 2½ miles northeast of. Drilled well owned by Kosko Coal & Gas Co.; water from Allegheny formation; large content of sodium and chloride probably due to contamination by waste brine from nearby oil well	50	H	8.8	.12	23	15	216	2.7	279	7.4	246	Trace	663	2.4	119	154
159	Chicora (Millerstown Borough). Drilled well 6⅝ inches in diameter and 60 feet deep; water from Worthington sandstone; owned by Millerstown Waterworks	50	H	8.4	[d].97	49	8.6	44	4.5	189	17	61	Trace	284	3.0	158	159
164	Butler, 3 miles west of. Drilled well 209 feet deep; water from shale just above Mahoning sandstone; owned by W. H. Bortmas	51	H	11	.28	24	8.1	44	2.0	209	8.1	1.3	Trace	201	3.5	93	164
167	Butler. Drilled well 8¼ inches in diameter and 225 feet deep; water from Clarion and Homewood sandstones; owned by Citizens Mutual Water Co. (well 7)	53	H	8.6	.20	22	6.6	319	9.9	[e]355	4.1	368	Trace	916	2.8	82	167
168	Butler. Drilled well 8 inches in diameter and 101 feet deep; water from carbonaceous shale facies of Middle Kittanning coal; owned by Butler Steam Laundry Co.	52.5	H	11	.08	16	1.4	106	2.9	227	4.2	56	Trace	307	2.7	46	168

177	Herman, ½ mile west of. Drilled well 5 inches in diameter and 75 feet deep; water from red shale at horizon of Cambridge limestone; owned by E. Steighner	50.5	H	13	.20	60	13	11	3.4	234	25	3.0	.52	236	3.6	203	177
191	Renfrew, 2 miles southeast of. Drilled well 176 feet deep; water from sandy shale at horizon of Brush Creek coal; owned by W. Fletcher	50	H	13	d2.2	6.4	3.0	5.5	1.8	43	7.6	2.2	Trace	62	2.0	28	191
192	Renfrew, 2¼ miles southeast of. Drilled well 6¼ inches in diameter and 105 feet deep; water from Saltsburg sandstone; owned by Philip Miller	52.5	H	14	d1.2	65	10	8.0	2.3	238	13	8.	Trace	238	1.5	204	192
1004	West Sunbury, 4 miles southeast of. Oil well which pumps from Hundred-foot sand; owned by Mr. Boyers and others	------	bH	------	d52	11,300	1,858	a34,740		20	42	78,900	------	------	------	------	1004
1011-A	Saxonburg, 5½ miles south of. Miller No. 1 gas well; water from Squaw sand (?) between 1,160 and 1,163 feet below the surface; owned by Mrs. Sarah Miller	------	bH	------	d51	8,708	1,472	a26,170		58	3	60,000	------	------	------	------	1011-A
1011-B	Saxonburg, 5½ miles south of. Miller No. 1 gas well; water from Murrysville sand, 1,178 feet below the surface	------	bH	------	49	975	200	a5,077		434	3	9,880	------	------	------	------	1011-B
	Allegheny County																
226	Warrendale, ⅓ mile west of. Drilled well 6¼ inches in diameter and 82 feet deep; water from Saltsburg sandstone; owned by Allegheny County Industrial School (cottage 18)	53	H	13	.16	48	15	59	6.1	304	24	21	.59	322	4.2	182	226
227	Warrendale. Drilled well 6¼ inches in diameter and 60 feet deep; water from shaly facies of Saltsburg sandstone; contaminated by waste brine from oil wells; owned by Warrendale Hotel	53	F	13	d.64	24	9.8	476	4.6	188	2.8	705	.50	1,358	3.0	100	227
228	Warrendale, ¾ mile southwest of. Drilled well 6¼ inches in diameter and 151 feet deep; water at base of Cambridge limestone; owned by Allegheny County Industrial School (cottage 19)	52	H	13	.18	38	12	44	3.1	278	17	3.7	.61	257	2.6	144	228

a Calculated.
b Approximate analysis only.
d Includes iron precipitated at time of analysis.
e Includes equivalent of 2.4 parts of carbonate (CO_3).

Analyses of representative waters—Continued.

No. on Figs. 35, 39	Description	Temperature (°F.)	Analyst	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate radicle (HCO_3)	Sulphate radicle (SO_4)	Chloride radicle (Cl)	Nitrate radicle (NO_3)	Total dissolved solids at 180°C	Loss on ignition	Total hardness as $CaCO_3$[a]	No. on Figs. 35, 39
231	Mars, 3 miles south of. Drilled well 8 inches in diameter and 135 feet deep; water from Saltsburg sandstone; owned by E. V. Babcock	50	H	------	[d].63	36	9.0	[a]14		173	14	.5	Trace	160	------	127	231
236	Bakerstown. Drilled well 6¼ inches in diameter and 72 feet deep; water from Saltsburg sandstone; owned by R. H. Marks	50	H	11	[d]3.3	97	22	51	6.1	300	80	87	5.3	517	22	333	236
248	Russellton, 3¾ miles northeast of. Drilled well 6¼ inches in diameter and 47 feet deep; water from shale below Upper Freeport coal; owned by J. F. Wray	52	H	8.4	.30	34	9.6	42	2.8	228	12	11	Trace	220	4.0	124	248
249	Tarentum, 1⅓ miles north of. Drilled well 6¼ inches in diameter and 70 feet deep; water from Freeport sandstone; owned by Frank Shearer	54	H	9.6	.14	5.2	1.4	217	7.4	[f]496	7.1	67	.62	565	4.4	19	249
280	McKees Rocks, 1½ miles northwest of (Norwood Community). Drilled well 6 inches in diameter and 85 feet deep; water from Morgantown sandstone; owned by Dr. Hanover	50	H	7.8	.30	88	42	9.8	5.3	351	103	14	1.1	457	12	392	280
299	Renton. Drilled well 6 inches in diameter and 132 feet deep; water from sandy red shale above Morgantown sandstone; at superintendent's house, Union Collieries Coal Co.	53	H	10	.16	59	13	11	3.2	196	37	19	4.0	250	9.0	201	299
302	Pitcairn, 2 miles north of (Monroeville community). Drilled well 5⅝ inches in diameter and 164 feet deep; water from Morgantown sandstone; owned by S. N. Clark	52	H	13	.05	5.8	2.2	143	2.1	[g]417	5.6	3.5	Trace	384	2.7	24	302

304	Imperial. Drilled well 6 inches in diameter and 48 feet deep; water from Morgantown sandstone; owned by Mrs. Martha Ross	53.5	H	12	.27	43	14	68	4.6	311	47	19	Trace	350	18	165	304
307	Oakdale, 1½ miles northwest of. Drilled well 5⅝ inches in diameter and 56 feet deep; water from Connellsville sandstone; owned by Joe Mathews	50	H	16	[d]2.6	143	34	21	6.2	379	199	11	1.8	644	20	497	307
308	McDonald, 1 mile east of. Drilled well 5⅝ inches in diameter and 425 feet deep; water from Morgantown, Saltsburg, and Buffalo sandstones; well No. 3 at Sturgeon naphtha plant of South Penn Oil Co.	50	H	14	[d].75	140	44	3,109	17	[h]422	14	4,925	Trace	8,595	60	530	308
309	McDonald, 1 mile east of. Drilled well 6 inches in diameter and 284 feet deep; water from Saltsburg sandstone; well No. 2 at Sturgeon naphtha plant of South Penn Oil Co.	50	H	9.0	[d]1.1	55	15	895	12	442	57	1,250	Trace	2,502	8.2	199	309
D	Russellton, 1 mile north of. Pool beneath active drips from roof of Russellton No. 2 mine of Republic Iron & Steel Co.; water from shale above Upper Freeport coal, before oxidation and before contact with rails or pumps	------	H	8.2	[d]1.9	12	1.8	275	7.7	294	379	13	.95	844	5.6	37	D
E	Russellton, 1 mile north of. Main drainage ditch on west side of Russellton No. 2 mine of Republic Iron & Steel Co.; water from shale above Upper Freeport coal after oxidation and after contact with rails	------	[b]H	------	[d]32	119	29	[a]354		0	[i]1,127	14	.84	1,644	------	416	E
	Washington County																
325	Florence, 4½ miles north of, in Beaver County. Frankfort Spring; water from Morgantown sandstone	49.5	F	19	[d].18	55	16	16	1.7	234	42	1.4	.28	261	2.1	203	325
326	Florence, 3¼ miles northwest of, at Frankfort compressing station of Manufacturer's Light & Heat Co. Drilled well 8 inches in diameter and 100 feet deep; water from Saltsburg sandstone	50	F	17	[d]1.7	36	9.0	34	2.4	224	5.3	9.0	.0	222	3.1	127	326
331	Midway, ¼ mile north of. Drilled well 5⅝ inches in diameter and 60 feet deep; water from Lower Pittsburgh limestone; owned by S. G. Beahout	50.5	F	10	[d].52	64	30	12	1.8	305	46	3.7	.15	321	8.6	283	331

[a] Calculated.
[b] Approximate analysis only.
[d] Includes iron precipitated at time of analysis.
[f] Includes equivalent of 9.6 parts of carbonate (CO_3).
[g] Includes equivalent of 19 parts of carbonate (CO_3).
[h] Includes equivalent of 7.2 parts of carbonate (CO_3).
[i] Includes 8.1 parts as free acid.

Analyses of representative waters—Continued.

No. on Figs. 39, 40	Description	Temperature (°F.)	Analyst	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate radicle (HCO_3)	Sulphate radicle (SO_4)	Chloride radicle (Cl)	Nitrate radicle (NO_3)	Total dissolved solids at 180°C	Loss on ignition	Total hardness as $CaCO_3$[a]	No. on Figs. 39, 40
332	Midway, ¼ mile east of. Drilled well 6¾ inches in diameter and 48 feet deep; water from Connellsville sandstone; supplies laborers' dwellings of Carnegie Coal Co.	50.5	F	17	.17	82	30	97	5.9	383	200	18	2.0	637	7.4	328	332
333	Burgettstown, ¼ mile west of. Drilled well 5⅝ inches in diameter and 82 feet deep; water from red shale accompanying Lower Pittsburgh limestone; owned by Burgettstown Coal Co.	52	F	24	[d]2.3	506	141	27	12	241	1,618	16	6.7	2,594	80	1,843	333
336	Burgettstown, ½ mile south of. Drilled well 5⅝ inches in diameter and 85 feet deep; water from red shale accompanying Lower Pittsburgh limestone; owned by Henry Tennyson	54	F	12	[d].70	73	27	32	5.0	45	210	38	75	495	26	293	336
346	Hickory. Drilled well 5⅝ inches in diameter and 126 feet deep; water from Uniontown limestone; owned by Hickory High School	53	F	16	.07	62	17	34	4.8	259	62	18	.83	330	2.2	225	346
356	Hickory, 3½ miles south of. Drilled well 5⅝ inches in diameter and 107 feet deep; water from sandy carbonaceous shale (Waynesburg coal); owned by Gretna Oil & Gas Co.	51.5	F	26	[d]1.3	83	18	12	2.2	333	23	2.6	.05	320	3.8	281	356
360	Finleyville, ¾ mile north of. Drilled well 5⅝ inches in diameter and 44 feet deep; water from Connellsville sandstone; owned by H. D. Benn	55.5	F	10	[d].80	108	22	8.2	3.7	286	130	1.4	.05	439	11	360	360
368	Washington. Drilled well 8 inches in diameter and 200 feet deep; water from Sewickley sandstone; owned by Washington Ice Co.	54	F	17	.07	63	18	244	6.1	477	77	218	.25	898	9.0	231	368
372	Washington, 2 miles southeast of, at Laboratory school. Drilled well 5⅝ inches in diameter and 100 feet deep; water from shale above Donley limestone, Greene formation	52	F	12	[d].81	120	7.3	8.2	3.2	272	61	20	40	411	11	330	372

389	Amity, 3 miles northeast of, at Lone Pine tory school. Drilled well 5⅝ inches in Co. Drilled well 5⅝ inches in diameter and 85 feet deep; water from Uniontown limestone	52	F	7.3	[d].22	2.8	2.1	445	9.6	[j]867	3.8	198	2.9	1,116	2.3	16	389
390	Amity, 2¼ miles north of. Drilled well 5⅝ inches in diameter and 64 feet deep; water from sandstone in lower part of Greene formation; owned by Ralph H. Keeney	52	F	17	[d].93	98	30	12	3.5	356	86	6.4	1.5	436	11	368	390
	Westmoreland County																
415	**Braeburn, 1⅞ miles southeast of.** Drilled well 8 inches in diameter and 140 feet deep; water from shaly facies of Mahoning sandstone; owned by Hillcrest Country Club	52	F	17	.17	40	13	43	1.3	261	18	9.0	.60	262	4.1	153	415
422	**Murrysville. Drilled well 8 inches in diameter** and 74 feet deep; water from Mahoning sandstone; owned by Murrysville High School	52	F	18	[d]1.1	47	13	11	1.1	217	2.6	8.0	.0	201	3.0	171	422
424	Export. Drilled well 5⅝ inches in diameter and 195 feet deep; water from gritty carbonaceous shale (Duquesne coal); owned by Tony Santucci	51	F	8.3	[d].52	2.9	1.4	253	4.6	[k]341	202	66	1.2	722	3.0	13	424
430	Jeannette. Drilled well 14 inches in diameter and 250 feet deep; water from Clarion sandstone; **owned by Pennsylvania Rubber Co.**	55.5	F	13	[d]8.2	98	24	403	9.2	293	85	644	1.0	1,449	17	343	430
	Jeannette. Drilled well 404 feet deep; water from Homewood sandstone; well 6 of Pennsylvania Rubber Co.		F	10	[d]5.1	70	27	835	12	510	4.9	1,200	1.5	2,458	5.0	286	
431	Slickville. Drilled well 12 inches in diameter and 225 feet deep; water from Buffalo sandstone; owned by Bethlehem Mines Corporation	53	F	12	[d].54	3.7	1.4	211	3.2	[l]469	62	29	.50	565	3.2	15	431
433	Delmont. Drilled well 5⅝ inches in diameter and 45 feet deep; water at base of Lower Pittsburgh limestone; owned by Paul Jobe	51	F	9.0	.08	81	6.2	2.7	0.7	209	42	14	8.3	272	8.0	228	433
438	Blairsville, 2½ miles west of. Drilled well 6¼ inches in diameter and 70 feet deep; water from shale at horizon of Cambridge limestone; owned by Liberty Bell Inn	52	F	16	[d].68	74	19	7.0	1.7	315	10	3.6	.05	280	6.0	263	438

[a] Calculated.
[d] Includes iron precipitated at time of analysis.
[j] Includes equivalent of 48 parts of carbonate (CO_3).
[k] Includes equivalent of 36 parts of carbonate (CO_3).
[l] Includes equivalent of 26 parts of carbonate (CO_3).

Analyses of representative waters—Continued.

No. on Figs. 40–38	Description	Temperature (°F.)	Analyst	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate radicle (HCO_3)	Sulphate radicle (SO_4)	Chloride radicle (Cl)	Nitrate radicle (NO_3)	Total dissolved solids at 180°C	Loss on ignition	Total hardness as $CaCO_3$[a]	No. on Figs. 40–38
442	Derry, ¼ mile east of. Drilled well 8 incbes in diameter and 450 feet deep; water from Pottsville sandstone; owned by American Window Glass Co.	50	F	12	[d]1.8	8.6	3.3	21	1.4	59	16	10	.10	102	1.0	35	442
445	New Florence, 4½ miles southwest of. Abandoned test boring 12 inches in diameter and 4,610 feet deep; principal yield of water from Burgoon sandstone at depth of 1,200 feet; owned by R. A. Ross; drilled by Peoples Natural Gas Co.	58	F	16	[d].23	5.2	1.5	131	2.9	224	4.0	86	.10	368	2.6	19	445
479	North Bellevernon, ¾ miles east of. Drilled well 5⅝ incbes in diameter and 60 feet deep; water from Redstone limestone; owned by G. H. Clark	51.5	F	19	[d].79	84	25	7.1	.8	273	72	18	.25	371	8.8	312	479
480	West Newton, ½ mile south of. Drilled well 5⅝ inches in diameter and 200 feet deep; water from Connellsville sandstone; owned by West Newton Water Co.	51.5	F	21	.08	26	9.7	71	1.3	[m]270	35	10	.05	292	3.0	105	480
489	Scottdale. Drilled well 8 incbes in diameter and 150 feet deep; water from Morgantown sandstone; owned by Scottdale Ice & Coal Co.	52.5	F	17	[d]14	74	18	17	2.1	149	129	24	1.1	374	8.0	259	489
496	Mammotb, 1¼ miles south of. Drilled well 4¼ incbes in diameter and 65 feet deep; water from Saltsburg sandstone (?); owned by W. G. Keck & Sons	52	F	16	[d].55	40	9.5	31	.7	206	18	9.0	.53	224	2.3	139	496
497	Mammoth, 1¼ miles soutb of. Drilled well 10 incbes in diameter and 104 feet deep; water from Saltsburg sandstone; owned by W. G. Keck & Sons	52	F	17	[d].36	40	9.0	26	1.0	190	21	6.2	.29	211	2.4	137	497

503	Stahlstown, ⅓ mile northwest of. Drilled well 4¼ inches in diameter and 66 feet deep; water from shale at horizon of Bakerstown coal; owned by Frank Hood	49	F	20	[d]23.2	16	6.5	5.0	1.0	54	26	2.7	.29	99	2.4	67	503
509	Jones Mills, ½ mile southwest of. Drilled well 4¼ inches in diameter and 43 feet deep; water from shaly facies of Mahoning sandstone; owned by Mrs. Jessie Friedline	50	F	10	[d]4.1	24	6.2	5.0	1.0	70	23	4.0	4.5	115	3.8	85	509
	Greene County																
510	Wind Ridge, ¾ mile northeast of. Drilled well 5⅝ inches in diameter and 77 feet deep; water from shale above Donley limestone; owned by John Burns	52	F	15	[d].84	78	10	7.1	2.2	223	15	7.2	29	274	12	236	510
519	Rogersville. Drilled well 5⅝ inches in diameter and 38 feet deep; water from sandstone at horizon of Jollytown coal; owned by John Ullom	52	F	17	.19	50	13	7.4	[m]2.0	168	20	18	5.2	218	9.0	178	519
527	Waynesburg. Drilled well 118 feet deep; water from Waynesburg sandstone; owned by Waynesburg Ice Co.	52.5	F	10	.19	33	12	589	11	447	3.1	752	.0	1,654	------	132	527
532	Waynesburg, 2⅜ miles south of. Drilled well 6⅝ inches in diameter and about 50 feet deep; water probably from Waynesburg sandstone; owned by Charles B. Orndoff	52	F	12	.14	34	8.4	171	5.6	426	3.0	102	.0	562	3.8	119	532
533	Jefferson. Drilled well 5⅝ inches in diameter and 36 feet deep; water from Waynesburg sandstone; owned by L. L. Cree	54.5	F	12	.19	39	16	54	4.0	29	120	37	98	390	15	163	533
540	Holbrook, 3½ miles south of. Drilled well 5⅝ inches in diameter and 87 feet deep; water from Nineveh sandstone; owned by Walter Lewis	51	F	10	[d]1.61	93	16	10	2.8	249	36	26	42	365	18	298	540
544	Kirby. Drilled well 5⅝ inches in diameter and 53 feet deep; water from shaly facies of Waynesburg sandstone (?); owned by Kirby school district	54	F	17	[d].24	43	12	67	1.4	321	26	4.0	2.5	325	5.0	157	544

[a] Calculated.
[d] Includes iron precipitated at time of analysis.
[m] Includes equivalent of 7.2 parts of carbonate (CO_3).

Analyses of representative waters—Continued.

No. on Figs. 38, 37	Description	Temperature (°F.)	Analyst	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate radicle (HCO_3)	Sulphate radicle (SO_4)	Chloride radicle (Cl)	Nitrate radicle (NO_3)	Total dissolved solids at 180°C	Loss on ignition	Total hardness as $CaCO_3$[a]	No. on Figs. 38, 37
550	Deep Valley. Drilled well 5⅝ inches in diameter and 92 feet deep; water from sandstone above Donley limestone; owned by George Grimm	53	F	15	.11	21	4.5	62	3.4	204	25	15	.25	246	2.7	71	550
560	Blacksville (Monongalia County, W. Va.). Drilled well 5⅝ inches in diameter and 250 feet deep; water from Waynesburg sandstone; owned by Mack Steele	54	F	20	[d].69	51	11	25	2.5	240	17	4.1	1.2	244	4.8	173	560
	Fayette County																
567	Fayette City, 1½ miles southeast of. Drilled well 5⅝ inches in diameter and 34 feet deep; water from Lower Pittsburgh limestone; owned by George Bedner	52	F	13	[d].55	128	27	28	3.2	384	116	42	.15	565	10	431	567
569	Perryopolis. Drilled well 5⅝ inches in diameter and 80 feet deep; water from soft shale at horizon of Clarksburg limestone; owned by John Armstrong	52	F	14	[d]1.0	50	26	8.4	2.0	106	9.9	54	100	304	13	232	569
570	Perryopolis, ⅓ mile south of. Drilled well 4¾ inches in diameter and 130 feet deep; water from Morgantown sandstone (?); owned by Jack Flannagan	54	F	14	.15	4.4	2.1	93	2.5	[n]253	3.1	13	.0	256	1.5	20	570
576	Connellsville, 1¾ miles northeast of (Coalbrook community). Drilled well 5⅝ inches in diameter and 40 feet deep; water from Connellsville sandstone; owned by J. E. Henderson	54	F	12	.17	80	20	51	9.6	161	88	58	136	532	22	282	576

577	Connellsville, 1¾ miles northeast of (Coalbrook community). Drilled well 5⅝ inches in diameter and 100 feet deep; water from shaly facies of Morgantown sandstone; owned by Clark Balsley	52.5	F	13	[d]1.1	5.6	2.4	176	2.6	[o]481	10	4.0	1.0	460	2.1	24	577
578	Mcleroft. Drilled well 4¼ inches in diameter and 58 feet deep; water from Worthington (U. Kitt.) sandstone; owned by Mcleroft Coal Co.	52.5	F	9.0	[d]5.2	18	7.6	14	1.4	110	6.8	5.7	.10	106	1.8	76	578
589	Connellsville. Drilled well 8 inches in diameter and 150 feet deep; water from Saltsburg sandstone (?); owned by Yough Brewing Co.	52	F	3.9	.19	17	3.0	5.0	.9	28	30	4.0	3.8	83	2.1	55	589
606	Lemont Furnace, 1¼ miles southeast of. Cool Spring; water from Connoquenessing sandstone; owned by Uniontown Borough	52	F	8.6	.16	25	4.1	.9	.6	63	22	2.5	1.9	98	1.7	79	606
617	Fairchance, 1¼ miles northeast of. Drilled well 5⅝ inches in diameter and 165 feet deep; water from Morgantown sandstone; flowing well at former Wynn coke plant of H. C. Frick Coal Co.	53	F	17	.10	36	11	30	1.6	219	17	4.5	.0	216	2.3	135	617
628	Point Marion, ½ mile south of. Drilled well 8 inches in diameter and 300 feet deep; water from Saltsburg sandstone at depth of 165 to 177 feet; owned by Point Marion Ice Co.		F	12	[d].23	31	9.8	114	2.6	224	80	60	13	433	6.0	118	628
633	Farmington, 1½ miles northwest of. Drilled well 5⅝ inches in diameter and 80 feet deep; water from Mahoning sandstone; owned by William Burley	52	F	7.9	[d].41	68	18	3.8	.6	223	26	12	20	262	6.7	244	633
635	Farmington, ⅔ mile southeast of. Drilled well 5⅝ inches in diameter and 393 feet deep; water from Homewood sandstone; owned by Gorley's Lake Hotel	51	F	9.1	[d].32	34	10	1.0	2.2	135	7.1	2.1	3.2	132	3.1	126	635

[a] Calculated.
[d] Includes iron precipitated at time of analysis.
[n] Includes equivalent of 8.9 parts of carbonate (CO_3).
[o] Includes equivalent of 54 parts of carbonate (CO_3).

WATERS FROM THE CONSOLIDATED ROCKS

The 80 samples of water collected from wells and springs which are supplied by the consolidated rocks comprise 39 calcium bicarbonate waters, 23 sodium bicarbonate waters, 11 sodium chloride waters, 5 calcium sulphate waters, 1 magnesium bicarbonate water, and 1 sodium sulphate water. The two samples of coal mine water (Nos. D and E, p. 75) include 1 sodium sulphate water and 1 acid sulphate water. The implication of such designations is that the quality of each sample is essentially that of a solution of the single compound named. Actually, however, the preponderance of one constituent over another may be very slight, and the suite of ground-water samples represents a nearly complete gradation from one type to another, as is shown by Figure 15.

On the upper of the two accompanying triangular diagrams are plotted the percentages of the reacting values (milligram equivalents) of the principal basic radicles in the natural waters, each dot representing one analysis. The quantity of calcium is measured along the line AB and projected parallel to AC, magnesium is measured along the line BC and projected parallel to BA, and the sum of sodium and potassium is measured along CA and projected parallel to CB. In any one analysis the sum of these components measured in percentage reacting value must equal 50, so that the lines projecting them must intersect at a point. For example assume that,

$$\begin{aligned} Ca &= 7.5 \text{ per cent reacting value.} \\ Mg &= 15.0 \text{ `` `` `` ``} \\ Na + K &= 27.5 \text{ `` `` `` ``} \end{aligned}$$

The lines projecting these quantities, which are shown by broken lines, intersect at point P, which represents the analysis.

Let the triangular diagram be divided into three equal areas by lines joining its center with the mid-points of the respective sides, as is shown by the small key diagram at the right. Then all dots which fall in the lower right segment, which is marked rCa on the key diagram, represent waters in which the reacting value of calcium is more than that of magnesium or of the sum of sodium and potassium. Also those dots which fall in the upper segment represent waters in which magnesium has the greatest reacting value, and those which fall in the lower left segment represent waters in which sodium and potassium have the greatest reacting value.

Similarly, on the lower diagram are plotted the percentages of the reacting values of the acid radicles, carbonate plus bicarbonate, sulphate, and chloride plus nitrate.

The large dots represent ground water from unconsolidated deposits, and the small dots ground water from consolidated rocks.

Shallow wells in southwestern Pennsylvania yield fresh water of moderate concentration, whereas deep wells generally find highly concentrated salt water. The saline water is believed to be modified connate water—that is, water which saturated the marine sediments at the time they were deposited but has doubtless been modified by solution of new substances, precipitation of substances out of solution, hydration of shale-forming minerals, osmosis, and other processes. As

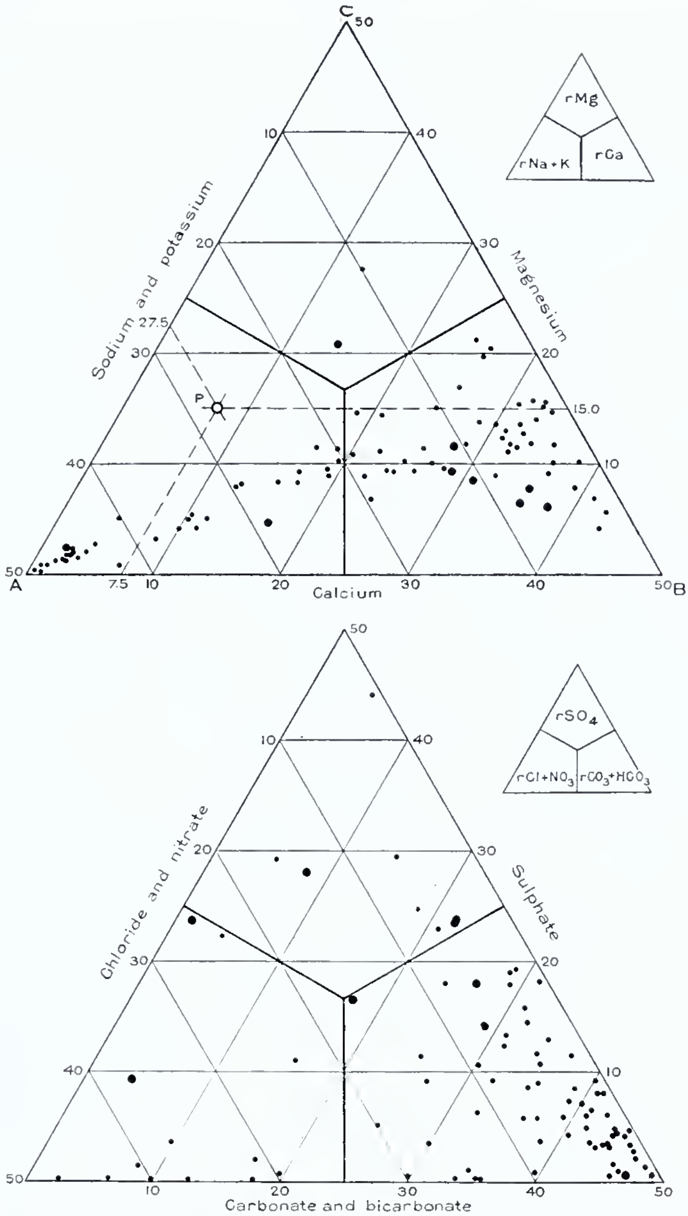

Figure 15.—Chemical character of ground waters in southwestern Pennsylvania. Quantities in percentage of reacting value (percentage of milligram equivalents).

a corollary it is believed that the fresh ground water is of meteoric origin and that it has flushed the salt water from the topmost rocks. Obviously, connate water will not be flushed from a bed unless it can be discharged at the surface at some point lower than that at which meteoric water enters the bed. If the rocks are readily permeable and the fresh water is under considerable hydrostatic head the time needed to flush out the connate water may be relatively short. On the other hand, where the rocks are not very permeable or the hydrostatic head is small, the rate of displacement may be extremely slow. Even in the permeable rocks the process can theoretically proceed only to such a depth below the point of discharge that the hydrostatic

pressure of the fresh-water column will balance that of the shorter column of heavier brine that is displaced, and the deeper connate water may remain virtually undiluted throughout long ages of geologic time.

In southwestern Pennsylvania most of the consolidated rocks are relatively impermeable, and the permeable beds are discontinuous. Moreover, in most of the area the rocks are only slightly folded. Hence, many of the permeable beds do not reach the surface, and water of meteoric origin can not circulate through them. On the low plateau west of Chestnut Ridge most if not all wells more than 500 feet deep and those which reach a level more than 100 feet below the beds of the principal streams pass through the zone of circulating ground water and find salt water below. Wells 286, and 308-9 (pp. 216, 228), for example, find salt water at comparatively shallow depths. These wells are between the West Middletown and Nineveh synclines (Pl. 1) and north of the Westland dome, a structural feature that impedes ground-water circulation. In the Allegheny Mountains section, however, the rocks are much more closely folded, some of the permeable beds are more continuous, and the relief of the land surface is much greater. Hence, the fresh water is under greater head, and the salt water has been flushed out to greater depth, as in well 445, (p. 374), which found fresh water more than 1,000 feet below the surface.

The tabulated analyses do not indicate any relation between the chemical character of the fresh ground waters from southwestern Pennsylvania and the geologic formations that embrace the water-bearing beds. The waters from each formation vary between wide limits of concentration and of hardness, and a single formation, the Conemaugh, yields the waters of greatest and least concentration and of greatest and least hardness among the entire suite of samples. Neither does the relative abundance of the dissolved constituents vary systematically according to the formation. As is brought out more fully in subsequent paragraphs, the differences in chemical character of the water depend most directly upon the depth of the water-bearing bed beneath the surface, and to a less degree upon the lithologic character of the water-bearing bed. Hence a close relation between quality of water and formation is not to be expected, for each formation comprises beds which differ in lithology to a similar degree. One outstanding exception to this generalization exists—the massive Pottsville sandstones, whose waters are as a rule slightly or moderately concentrated and relatively soft where the beds are not deeply buried.

Hard waters

The uppermost ground waters from the consolidated sediments of southwestern Pennsylvania are usually calcium bicarbonate waters which are rather hard in proportion to the concentration. This is true of waters from all kinds of rocks. Generally, these shallow waters contain much less sulphate (SO_4) than bicarbonate (HCO_3), so that the noncarbonate hardness, or so-called permanent hardness, is relatively low. If the different kinds of rocks are arranged in the order

of increasing average proportion of the calcium ion in their respective waters, this sequence is also that of increasing proportion of the sulphate radicle (SO_4). Hence, it is the order of increasing total hardness and noncarbonate or permanent hardness in so far as the waters are of similar concentration. This sequence of rock types in order of increasing hardness of their respective waters is, coal or carbonaceous shale, sandstone, gray shale, limestone, and red shale. However, the difference between the waters from any two kinds of rock is not great. Some thick beds of brilliant red shale which are accompanied by beds of limestone contain gypsum and possibly other soluble substances and yield water which is very hard in proportion to the concentration, as is represented by analysis 333 (p. 76). Still other beds of red shale which are not accompanied by limestone may yield only moderately hard water, comparable to that found in the light-colored gray shale.

Analysis 567 (p. 80) represents a water in which the sulphate has been partly reduced where the water-bearing bed lies at shallow depth. This water is from a well 33 feet deep that taps the Upper Pittsburgh limestone 25 feet below the surface. It contains a moderate quantity of dissolved iron, and the sulphate radicle is equivalent in chemical activity to about one-third of the other acid constituents. As water is pumped from the well it is clear and has a slight odor of hydrogen sulphide (H_2S), but after it has stood for about 5 minutes it becomes slightly murky, and in the course of an hour it becomes bluish black. This phenomenon is due to the formation of a suspended precipitate of ferrous sulphide (FeS) by reaction of the hydrogen sulphide with the dissolved iron in the presence of air as an oxidizing agent. The precipitate flocculates very slowly and remains in suspension many hours, so that the water is unsatisfactory for household uses. The hydrogen sulphide is presumably a product of reduction of the sulphate radicle. The reducing agent may be a hydrocarbon gas derived from a bed of coal or carbonaceous shale, although no such gas is known to be present in the water. It seems equally probable that the reduction may be effected by certain anaerobic bacteria which, in the presence of organic matter, reduce sulphate compounds to hydrogen sulphide. The functions of such bacteria have been studied by many workers, whose work has been reviewed by Rogers.[54]

Soft waters

Many of the water-bearing beds—whether they are sandstone, shale, or limestone—contain soft sodium bicarbonate water where they lie at intermediate depths. This soft water is believed by the writer to represent calcium bicarbonate water that has exchanged its calcium and magnesium for sodium by reaction with base-exchange silicates in the rock as it has percolated downward along the dip of the water-bearing bed. The hardness due to the bicarbonate of calcium and magnesium is removed in proportion to the completeness of the exchange reaction. and the water finally passes into the sodium bicarbonate type. The base exchange silicates which are active in southwestern Pennsylvania are presumably the clay-forming minerals of the montmorillonite and

[54] Rogers, G. S., Chemical relations of the oil-field waters in San Joaquin Valley, Calif. ; U. S. Geol. Survey Bull. 653, pp. 95-97, 1917.

hydro-mica groups, whose molecules carry a variable proportion of adsorbed sodium that is available for chemical reaction.[55] Clay-forming minerals are present in the shale, the earthy sandstone, and the thin-bedded limestone, and hence the exchange of bases takes place in all these rocks. Renick[56] has also concluded that soft waters from rocks of Tertiary age in east-central Montana have been formed by reaction with base-exchange silicates.

The rapidity of the natural softening depends on the length of time that the hard water remains in contact with active base-exchange silicates. Hence, it depends indirectly on the depth of the water-bearing bed beneath the surface, in so far as the depth is a measure of the time required for the water to percolate from the surface along the dip of the bed. Lateral variations in the permeability of the bed cause differences in the rate of percolation and in the rate of the exchange reaction. In the gently folded rocks of the Kanawha section the critical conditions are relatively uniform so that the softness of the water at a given depth can be roughly predicted. In the Allegheny Mountains of Westmoreland and Fayette counties, however, the beds are more closely folded, the hydrostatic head is greater, and many of the rocks are more permeable than in the Kanawha section. Consequently, the ground water circulates more rapidly, and at a given depth below the surface the process of base exchange is less complete.

The completeness of the base-exchange reaction in the bicarbonate waters is measured by the ratio between the calcium and sodium ions, a small ratio indicating a soft water. In the Kanawha section of southwestern Pennsylvania the calcium-sodium ratio of the ground waters seems at first glance to bear no systematic relation to the depth of the water-bearing bed. If, however, the depth of the water-bearing bed is expressed with reference to the level of near-by surface streams, the systematic relation between depth and calcium-sodium ratio becomes apparent. Where the water-bearing bed is above drainage level, exchange of bases proceeds very slowly if at all, and the water is hard. Where the water-bearing bed is below drainage level, however, base exchange is active, and the water becomes progressively softer at greater and greater depths.

The type example for the process of base exchange in the Kanawha section of southwestern Pennsylvania is a suite of six samples of water from the Morgantown sandstone member (see p. 163). These samples came from wells 280, 302, and 304 of Allegheny County (pp. 244, 230, 228), well 325 of Washington County (p. 346), and wells 570 and 577 of western Fayette County (pp. 302, 294). The chemical character of the waters is shown by the analyses tabulated on pages 74-80 and by Figure 16. The diagram shows that the exchange of the calcium and magnesium for sodium is slight where the water-bearing bed lies above drainage level but is virtually complete where the water-bearing bed is 75 to 100 feet below drainage level. A similar rate of exchange prevails in the other consolidated rocks of the Kanawha section, and few of the ground waters are high in carbonate hardness if the water-bearing bed is more than 75 feet below drainage level.

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[55] Ross, C. S., personal communication.

[56] Renick, B. C., Base exchange in ground water by silicates as illustrated in Montana: U. S. Geol. Survey Water-Supply Paper 520, pp. 53-72, 1925.

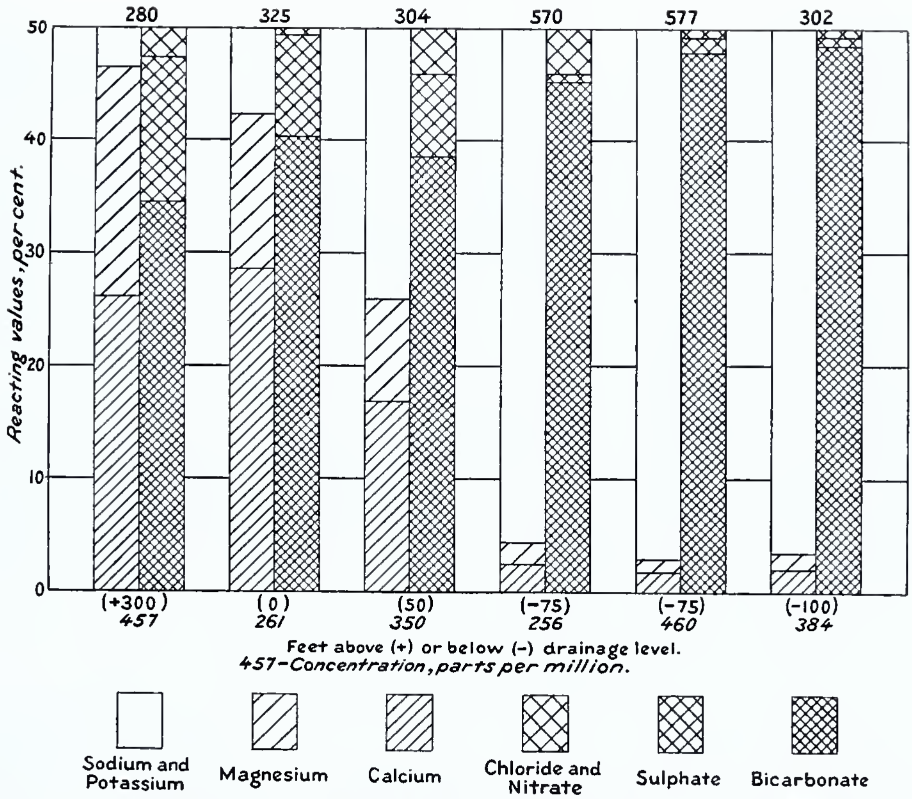


Figure 16.—Diagram illustrating natural softening of the water in the Morgantown sandstone by reaction with base-exchange silicates of the rock.

Iron-bearing waters

The waters which occur in beds of "sulphur"-bearing coal or in the pyritiferous shales that accompany them usually have a relatively high content of dissolved iron. Such waters, which are known to well drillers as "red" water or "sulphur" water, stain linens and utensils if used for household supply, form a sludge in storage tanks and pipes, and are unfit for many industrial purposes. Furthermore, they favor the growth of crenothrix and other filamentous iron-secreting algae. The capacity of many of the wells in southwestern Pennsylvania is much less than the capacity of the respective pumps, so that the water level may be drawn down so far by pumping that the water-bearing bed is exposed to the air. If the water of such a well contains dissolved iron, oxidation may occur in the water-bearing bed and the pores of the bed may be gradually closed by iron oxide. Several wells whose specific yield has apparently been reduced by such interstitial deposition of iron oxide have been reported from southwestern Pennsylvania.

When water which has a high content of dissolved iron is in contact with the air it becomes acid by oxidation and hydrolysis and hence becomes corrosive. Two samples of water from the No. 2 mine of the Republic Iron & Steel Co., at Russellton, Allegheny County, are instructive. One (analysis D, p. 75) is representative of the quality of the water as it exists in the roof shales above the Upper Freeport coal bed. This is a highly concentrated sodium sulphate-bicarbonate water that contains 1.9 parts per million of dissolved iron. In contact

with the oxygen of the air, sulphuric acid is formed by oxidation of the ferrous sulphate and reacts with the bicarbonate radicle (HCO_3). As oxidation proceeds, the bicarbonate may be wholly neutralized, the water becomes acid and is able to corrode metals and to dissolve calcium and magnesium from rock-forming minerals. The second of the two samples (analysis E, p. 75) was taken from the mine drainage ditch after it had been thoroughly oxidized and had come into contact with the steel rails of the haulageways, pipes, and other metallic objects. This is an acid sodium sulphate water that is approximately twice as concentrated as the water directly from the roof shales. However, the concentration of iron is 17 times as great as in sample D, calcium is 10 times as great, magnesium is 16 times as great, and sulphate is 3 times as great. The bicarbonate of the unoxidized water has been completely neutralized. Furthermore, 8.1 parts per million of the sulphate radicle exist as free acid. Although the two samples are not strictly quantitative equivalents, they show that the oxidized water has been changed by the addition of iron, calcium, and magnesium and the complete loss of bicarbonate.

Some modifications of casing practice to combat the corrosive iron-bearing waters have been discussed on pages 45-46.

Brackish Waters and Brines

In many parts of southwestern Pennsylvania the beds containing nonsaline "top" waters are underlain by several hundred feet of dry shale, below which the permeable beds contain very highly concentrated sodium chloride waters or brines. Certain of these brines are as much as 7.5 times as concentrated as sea water. In other places the rocks are more permeable, and the fresh water and brines are generally separated by "brackish" waters that are mixtures of the two. The change from the bicarbonate waters to chloride water is, however, rather sharp, as in the principal stream valleys in the northern part of the region, where the stratigraphic section includes many permeable beds. Nonsaline waters are not known to exist beneath the uppermost notably saline water at any point within the area studied. However, a very highly concentrated brine may be underlain by a brine that is much less concentrated and may be erroneously described as "fresh" water by the driller.

Regarding the origin of the deep-seated brines of the Appalachian basin, of which typical examples are furnished by analyses 1004 and 1011 (p. 73), Mills and Wells[57] state:

"The deep-seated brines of the Appalachian oil and gas fields, as viewed by us, are only in part the derivatives of waters of sedimentation which were included when the sediments were deposited. The chlorine in the brines has been derived directly or indirectly from the waters of sedimentation, but practically all the other noteworthy constituents have been derived, at least in part, from other sources.

"Extensive migration and the partial expulsion of the originally included waters have been caused by the consolidating processes to which the sediments have been subjected, more especially by compacting due to the increasing weight of subsequently deposited material.

[57] Mills, R. van A., and Wells, R. C., The evaporation and concentration of waters associated with petroleum and natural gas: U. S. Geol. Survey Bull. 693, pp. 67-68, 1919.

Cementation, heat, rock movements, and the incursion of petroleum and natural gas have also taken part in causing the migration and the expulsion of the interstitial waters.

"During periods of erosion ground waters of meteoric origin have from time to time entered the sedimentary rocks and have been retained and buried together with the waters of sedimentation or their derivatives. The final retention of the waters has been due to deep burial under relatively impermeable covers, to the sealing of the rock interstices, and to the basin-like structure of the Appalachian geosyncline.

"Profound changes in the waters subsequent to their inclusion in the sediments have resulted from the mere solution of certain rock constituents such as chlorides, sulphates, carbonates, and silicates; from organo-chemical processes such as the reduction of sulphates during the decomposition of organic matter; from chemical reactions brought about through the mixing of waters having different properties of reaction; from reactions due to heat; and from reactions between the dissolved constituents of the waters and the constituents of the rocks with which the waters have been in contact.

"The waters have also undergone deep-seated concentration. This concentration, which we believe to have been an important factor in many of the changes that the waters have undergone, was assisted in some places by heat and very generally by moving or expanding gases, which have carried off water as vapor. The concentration thus brought about has been accompanied by the loss from the waters of certain dissolved constituents, such as carbon dioxide, together with other gases, carbonates of iron, calcium, and magnesium, small amounts of sulphates of barium, strontium, and calcium, and also small amounts of silica as quartz or combined with other minor constituents. Under favorable conditions the concentration has proceeded to the extent of causing the separation of sodium chloride with minor proportions of calcium, magnesium, and potassium chlorides."

In the following table the characters of several deep-seated brines from southwestern Pennsylvania are compared to that of sea water. The factor of concentration is eliminated by expressing each constituent of an analysis as a percentage of the sum of the reacting values of all constituents. [58]

In sea water calcium is less than magnesium, the ratio being 0.196, whereas the brines are more concentrated in calcium than in magnesium. In the four brines whose analyses are entered in the table the calcium-magnesium ratio ranges from 6.05 to 2.96. Furthermore, sulphate (SO_4) makes up 9.3 per cent of the nonmetallic constituents of sea water, as measured in reacting value, but is virtually absent from the brines. With the exception of No. 1011-B, the brines contain bicarbonate (HCO_3) only in very small proportion, although it is appreciable in sea water. The relative abundance of these constituents is diagnostic as to the origin of the brines and shows that they could not have been formed from sea water merely by concentration or dilution. Brine 1011-B is an intermediate type between the deep-seated brines and the nonsaline ground waters although it came from a greater depth than brine 1011-A. That it is an intermediate type is shown

[58] Palmer, Chase, The geochemical interpretation of water analyses: U. S. Geol. Survey Bull. 479, pp. 5-11, 1911.

by the relatively high content of bicarbonate and the relatively low calcium-magnesium ratio.

Comparison between ocean water and deep-seated brines from southwestern Pennsylvania.

(Quantities in percentage of reacting values)

	Ocean water	Deep-seated brines, southwestern Pennsylvania			
		1004	1011-A	1011-B	1046
Iron (Fe)		[a]0.04	[a]0.05	[a]0.31	0.06
Calcium (Ca)	1.74	12.66	12.83	8.51	14.00
Strontium (Sr)					.90
Barium (Ba)					Trace
Magnesium (Mg)	8.86	3.43	3.57	2.88	2.31
Sodium (Na)	38.58	[b]33.87	[b]33.55	[b]38.30	31.26
Potassium (K)	.82				1.47
Carbonate (CO_3)	.05				None
Bicarbonate (HCO_3)	.15	.01	.03	1.24	
Sulphate (SO_4)	4.63	.02	.002	.01	.01
Chloride (Cl)	45.12	49.97	49.97	48.73	49.91
Bromide and iodide (Br+I)	.05				.08
Nitrate (NO_3)				.020	
	100.00	100.00	100.00	100.00	100.00
Concentration, parts per million	33,010 to 37,370	132,000	96,480	16,600	263,640

[a] Includes iron precipitated at time of analysis.
[b] Calculated.

Ocean water. Mean of 77 analyses from many localities, collected by the **Challenger** expedition, W. Dittmar, analyst. **Challenger** Rept., Physics and chemistry, vol. 1, p. 203, 1884. Analysis revised to show bicarbonate by R. C. Wells, U. S. Geol. Survey Prof. Paper 120, p. 15, 1918. Recalculated by A. M. Piper in terms of percentage reacting value.

1004. Brine from Hundred-foot sand, of uppermost Devonian (?) age. Well on Boyers farm, 4 miles southeast of West Sunbury, Butler County. Specific gravity of water, 1.098. C. S. Howard, analyst; approximate analysis.

1011-A. Brine from Squaw sand, of Pocono formation of lower Mississippian age; depth 1,160 feet. Gas well No. 1, Mrs. Sarah Miller farm, 5½ miles south of Saxonburg, Butler County. C. S. Howard, analyst; approximate analysis.

1011-B. Brine from Murrysville sand of lower Mississippian age; depth 1,178 feet. Well same as sample 1,011-A. C. S. Howard, analyst; approximate analysis.

1046. Brine from sandstone of Oriskany (Lower Devonian) age; depth 6,260 to 6,270 feet. Peoples Natural Gas Co. test well 770 on R. A. Geary farm, 2½ miles north of Midway, Washington County. Specific gravity of water, 1.211. George Steiger, analyst. (Clarke, F. W., Water analyses from the laboratory of the United States Geological Survey: U. S. Geol. Survey Water-Supply Paper 364, p. 9, 1914.)

Samples 308 and 309 (p. 75) are representative of the "brackish" waters, or those intermediate in composition between the non-saline waters and the deep-seated brines. For purposes of comparison these analyses are also expressed in percentage of reacting values. In these waters also, calcium exceeds magnesium, although both constituents are relatively less abundant and the calcium-magnesium ratio is smaller than in the typical deep-seated brines. In analyses 308 and 309 the ratio is 1.93 and 2.22, respectively. Furthermore, both bicarbonate and sulphate are more abundant in the intermediate waters, both relatively to other constituents and by concentration.

Composition of "brackish" waters from southwestern Pennsylvania.

(Quantities in percentage of reacting values.)

	308	309
Iron (Fe)	[a]0.01	[a]0.04
Calcium (Ca)	2.39	3.18
Magnesium (Mg)	1.24	1.43
Sodium (Na)	46.21	45.00
Potassium (K)	.15	.35
Carbonate (CO_3)	.08	----
Bicarbonate (HCO_3)	2.28	8.29
Sulphate (SO_4)	.10	1.36
Chloride (Cl)	47.54	40.35
Nitrate (NO_3)	----	----
	100.00	100.00
Concentration, parts per million	8,798	2,723

[a]Includes iron precipitated at time of analysis.

308. Water from Morgantown, Saltsburg, and Buffalo sandstone members of Conemaugh formation. Well 3 at Sturgeon naphtha plant, South Penn Oil Co., depth 425 feet; 1 mile east of McDonald, in Allegheny County. C. S. Howard, analyst.

309. Water from Saltsburg sandstone member of Conemaugh formation. Well 2 at Sturgeon naphtha plant, South Penn Oil Co., depth 284 feet; 1 mile east of McDonald, in Allegheny County. C. S. Howard, analyst.

SEQUENCE AND WATER-BEARING PROPERTIES OF THE ROCKS

GENERAL CHARACTER AND AGE

As has been brought out by the discussion of geologic history, the rocks of southwestern Pennsylvania are of sedimentary origin, except a single intrusive body of igneous rock. The sedimentary rocks exposed at the surface or penetrated by the drill present a complete sequence from the middle Silurian to the Permian and a partial sequence of the Quaternary. The entire Mesozoic era and the entire Tertiary period, however, are not represented. Most of the stratigraphic divisions are characterized by marked lateral variations so that the stratigraphic relations and water-bearing properties of the rocks are rather complex. The stratigraphic sequence and general lithologic characters of the rocks are summarized in the following table. The broad features of the sequence are also shown graphically by the columnar section which constitutes a portion of the geologic map (Pl. 1). Furthermore, each of the stratigraphic units is described in detail in succeeding paragraphs, and its water-bearing properties are analyzed as fully as the information at hand will permit.

Description of the stratigraphy of southwestern Pennsylvania is complicated further by the many local names which have been applied by well drillers to certain of the rock members. Moreover, most of these local names differ from the accepted geologic names. For example, the local term Bluff sand has been applied in various parts of the area to at least ten different stratigraphic units, the uppermost and lowermost of which are separated by 1,850 feet of beds. On the other hand, the stratum known to geologists as the Clarion sandstone has been designated by eight or more different names by the drillers. The following table, which correlates drillers' terminology with the accepted geologic nomenclature, is presented in order to make the ensuing discussion of stratigraphy and water-bearing properties as widely applicable as possible.

Composite stratigraphic section for southwestern Pennsylvania.

System	Series	Formation	Thickness (feet)	Character of strata	Water-bearing properties
QUATERNARY	RECENT	Alluvium	----	Fine gravel and sand from re-worked glacial valley train mingled with present day silt.	Succession and texture of beds, and consequently water-yielding capacity, vary from place to place. Yields 200 to 600 gallons per minute to adequately constructed wells in strategic locations. Water hard and locally has large iron content.
	PLEISTOCENE	Late glacial (Wisconsin) gravel	150	Allegheny-Ohio valley train, which extends from 100 feet above to 50 feet below low water. In eastern part of region comprises well-rounded cobbles up to 3 inches diameter, erratic boulders up to 12 inches diameter, and a matrix of sand and clay. Becomes finer and more uniform downstream (westward).	
		Lowest terrace gravel	0-15	Sand, silt, clay, and rounded pebbles of local derivation on low terraces which grade into present flood plains. Confined for the most part to the Monongahela Valley and other tributaries of the Ohio and Allegheny Rivers.	Subject to complete drainage at most localities; not highly productive of ground water.
		Intermediate glacial gravel	----	Ice-borne gravel, sand, and clay on sloping rock shelves below 820 feet altitude in the Ohio Valley.	
		Early glacial (Illinoian) gravel	5-25	In Allegheny-Ohio valley, deeply-decayed high terrace gravel, sand, and silt of glacial and local material derived from sedimentary and crystalline rocks as far north as Canada. In northern Butler County stratified sand, clay, and fine gravel of frontal apron.	Clayey facies of valley train yields supplies for household use from perched and semi-perched bodies of ground water; more permeable facies are subject to drainage. Permeable beds of frontal apron yield supplies of moderate magnitude.
		Carmichaels formation	60-70	High terrace sand, silt, and clay of local derivation and of approximately same age as the Illinoian gravel; contains a few deeply-decayed ill-rounded boulders; coarser at base. Confined to the Monongahela and other tributary valleys in the southern part of the area.	Variable in water-bearing properties; 5 to 10 gallons per minute may be obtained from coarser layers not subject to drainage.

CARBONIFEROUS	PERMIAN DUNKARD GROUP	Greene formation	725	Soft shale and shaly sandstone with some massive sandstones, a few thin limestones, and thin coal beds of no commercial value; much red shale in thin lenticular beds.	Coarse-grained facies of sandstones yield moderate supplies locally. Shales yield small supplies from bedding plane passages in vicinity of outcrop but are impermeable beneath thick cover. Waters are moderately concentrated; hard calcium bicarbonate waters at shallow depth, soft sodium bicarbonate waters below; some waters high in dissolved iron.
		Washington formation	275–440	Variable alternating strata of fine-grained shale and sandstone, with thin-bedded discontinuous limestones and several beds of coal of commercial value locally. Differs from Greene formation in being more evenly bedded and more calcareous, also in coal beds being thicker and more persistent.	Basal sandstone member yields at rates up to 65 gallons per minute where below drainage level, although remainder of formation is a poor water-bearer. Sandy shale and limestone yield supplies of household magnitude from bedding planes and joints beneath shallow cover but are impermeable at depth. Waters moderately concentrated and usually of good quality.
	PENNSYLVANIAN	Monongahela formation	260–400	Massive and thin-bedded limestone, variable shales, discontinuous sandstones, and several coal beds of economic importance; Pittsburgh coal at base. In northern part of outcrop area half the total thickness is made up of limestone; toward the south, the formation becomes more sandy and red shale enters the section.	Limestone beds yield as much as 25 gallons per minute from bedding planes and joints where just below drainage level; sandstone beds are locally less erratic but less productive water-bearers. Formation is not water-bearing beneath thick cover. Shallow waters hard; soft sodium carbonate waters below, which may be highly concentrated.
		Slight unconformity			
		Conemaugh formation	500–750	Gray or greenish and red shales with discontinuous sandstones, thin marine and fresh-water limestones, and local discontinuous beds of coal; lower 200 feet dominantly sandy. All members variable in thickness and lithology.	Sandstone members yield as much as 100 gallons per minute, though water-yielding capacity varies greatly from place to place; moderately concentrated hard calcium carbonate waters at drainage level pass to soft sodium carbonate waters below; highly concentrated brine at great depth. Shale and limestone members yield supplies of household magnitude at shallow depth but are impermeable beneath thick cover; waters of inferior quality and highly concentrated locally.
		Allegheny formation	250–370	Olive-green and drab shales which are ferruginous in lower third of formation, thin fine-grained to conglomeratic sandstones, also a few discontinuous marine limestones, and coal beds of economic importance. All members extremely variable in thickness and lithology.	Sandstone members yield as much as 300 gallons per minute, though varying most erratically and abruptly in water-yielding capacity; moderately concentrated hard calcium carbonate waters near surface, soft sodium carbonate waters below, very concentrated brines at depth, iron content large in some members. Shale, limestone, and coal members yield small supplies near their outcrops but are impermeable beneath continuous thick cover.
		Pottsville formation	65–250	Massive and heavy-bedded sandstones which are locally conglomeratic, with parting of variable shales and discontinuous thin beds of coal, fireclay, and limestone.	Moderate though relatively uniform permeability over extensive areas, drilled wells yielding 5 to 20 gallons per minute. Slightly to moderately concentrated hard calcium carbonate waters near surface, softer sodium carbonate waters below, very concentrated sodium chloride brines at depth.
		Unconformity			

Composite stratigraphic section for southwestern Pennsylvania—(Continued).

System	Series	Formation	Thickness (feet)	Character of strata	Water-bearing properties
CARBONIFEROUS	MISSISSIPPIAN	Mauch Chunk formation	0–310	Red, gray, and green shales with marine limestones and coarse green to gray sandstone in the lower portion.	Crop out over very limited area and are impermeable beneath thick cover, hence not important sources of water.
		Loyalhanna limestone	0–60	Siliceous limestone.	
		Pocono formation	650±	Massive sandstones, locally conglomeratic, with olive-green and gray shale; sandstone members more lenticular and thinner in lower half. Burgoon sandstone at top. Base of formation not exposed within the region.	Burgoon sandstone has high and uniform permeability, yielding as much as 150 gallons per minute or more to drilled wells. Water of inferior quality at moderate depth in northern Butler County, of good quality in eastern part of region; yields highly concentrated brines elsewhere. Shales are impermeable beneath cover, lower sandstone members yield concentrated brine within region.
DEVONIAN	UPPER DEVONIAN	Catskill formation	500–700	Red shale and thin lenticular white sandstones, gray and green beds making up 20 per cent of the whole. Known only from deep wells of the petroliferous districts.	Sandstone lentils yield a very small quantity of brine in a small proportion of the deep wells; shales impermeable.
		Chemung formation	900–1,200	Chocolate-colored shales and thin sandstone in upper part, gray and green beds below. Interfingers with Catskill above and not sharply separated from the Portage below. Known only from deep wells.	Sandstone lentils rarely yield a very small quantity of concentrated brine; formation not usually water-bearing.
		Portage formation	1,000–1,500	Greenish gray sandy shale with a few thin variable sandstones and lenticular limestones. Known only from deep wells.	Not water-bearing.
		Genesee shale	30(?)	Fine-grained black shale with layers of sandy limestone. Known only in a few test wells.	Not water-bearing.

Correlation of drillers' terms with geologic names of principal water-bearing rocks in southwestern Pennsylvania.

Name applied by driller, arranged alphabetically not stratigraphically	Geologic horizon: Formation	Geologic horizon: Division	Approximate average interval from Pittsburgh coal to top of bed Feet + = above; — = below	Remarks
Big Dunkard sand	Conemaugh	Saltsburg sandstone	— 400	Erroneous usage in Fayette and Washington counties where Mahoning sandstone is not recognized.
		Mahoning sandstone	— 525	General usage.
	Allegheny	Freeport sandstone	— 680	Local usage in Washington County where this sandstone is thick.
		Worthington sandstone	— 750	Local usage in Washington County where this sandstone is thick.
		Clarion sandstone	— 880	Local usage in Allegheny County where Clarion sandstone is thick.
Big Injun sand	Pottsville	Homewood and Connoquenessing sandstones	— 950	Erroneous usage locally in Washington County where the horizon of the Mercer shale member is filled by sandstone.
	Pottsville Pocono	Connoquenessing sandstone Burgoon sandstone	—1,025	Local usage in Butler, Allegheny, and Westmoreland counties where the Connoquenessing sandstone rests directly upon the Burgoon sandstone.
	Pocono	Burgoon sandstone	—1,250	General usage. The Loyalhanna limestone is included by many drillers in the top of the Big Injun sand.
	Pocono Catskill	Murrysville sand Gantz and Fifty-foot sands	—1,775	Local erroneous usage in Fayette County where Murrysville, Gantz, and Fifty-foot sands coalesce into a single sandstone unit.
Blue sand	Conemaugh	Connellsville sandstone	— 65	Local usage in northern Washington County.
Bluff sand	Greene	Fish Creek sandstone	+ 900	Loose usage in Greene and Washington counties where this member is thick.
	Washington	Washington sandstone	+ 450	Loose usage in Greene and Washington counties where this member is thick.
		Waynesburg sandstone	+ 375	General usage in Greene and Washington counties.
	Monongahela	Uniontown sandstone	+ 285	Loose usage in Greene and Washington counties where this member is thick.
	Conemaugh	Saltsburg sandstone	— 350	Usage in Butler County.
		Mahoning sandstone	— 525	
	Allegheny	Freeport sandstone	— 680	Loose usage where this member is thick.
		Worthington sandstone	— 750	Loose usage where this member is thick.
		Kittanning sandstone	— 835	Loose usage where this member is thick.
	Pottsville	Homewood sandstone	— 950	
Dunkard sand				Equivalent to either the Little Dunkard or Big Dunkard sands where only one is present or to both where they coalesce into a single sandstone.

Correlation of drillers' and geologic names of rocks—(Continued).

Name applied by driller, arranged alphabetically not stratigraphically	Geologic horizon			Remarks
	Formation	Division	Approximate average interval from Pittsburgh coal to top of bed Feet + = above; — = below	
Eighty-foot sand	Allegheny	Kittanning sandstone Clarion sandstone	— 835	Local term used in Allegheny County where the Kittanning and Clarion sandstones coalesce.
Forty-foot sand	Allegheny	Clarion sandstone	— 880	General usage in Butler County where Clarion sandstone is thick.
	Pottsville	Connoquenessing sandstone	—1,025	Local usage in Allegheny County.
	Pocono	Burgoon sandstone, upper division	—1,250	Local usage in Allegheny County where an upper division of the Burgoon sandstone is persistent.
	Mauch Chunk	Maxton sand?	—1,225	Local erroneous usage of driller's term.
Gas sand	Allegheny	Butler sandstone	— 640	Local usage in Allegheny, Greene, and Washington counties.
		Freeport sandstone	— 680	Local usage in Allegheny, Greene, and Washington counties.
		Worthington sandstone	— 750	Local usage in Allegheny, Greene, and Washington counties.
		Clarion sandstone	— 880	Erroneous usage in Butler County.
	Pottsville	Homewood sandstone	— 950	Local usage in Allegheny County.
		Connoquenessing sandstone	—1,025	Local usage in Allegheny County.
	Pocono	Murrysville sand?	—1,775	Also called First Gas sand and Butler gas sand. General usage in Allegheny, Butler, and Westmoreland counties.
Gas sand, Second	Pocono	Murrysville sand?	—1,850	Also Butler Thirty-foot sand. Local usage in Allegheny, Greene, and Westmoreland counties.
Gray sand	Pocono	Squaw sand?	—1,600	Local term in northern Butler County.
Hurry-up sand	Conemaugh	Saltsburg sandstone	— 350	Local usage in Allegheny and Washington counties where Mahoning sandstone is shaly.
		Mahoning sandstone	— 525	General usage.
Indian sand	Conemaugh	Morgantown sandstone	— 165	Local usage in Westmoreland County.
Little Dunkard sand	Conemaugh	Saltsburg sandstone, lower portion	— 400	General usage.
	Conemaugh	Mahoning sandstone	— 525	Erroneous usage where Saltsburg sandstone is shaly.
	Allegheny	Clarion sandstone	— 880	Erroneous usage in Allegheny County.
	Pottsville	Homewood sandstone	— 950	Erroneous usage in Allegheny County.
Mountain sand	Conemaugh	Morgantown sandstone	— 165	Local usage in Fayette County.
	Allegheny	Worthington sandstone	— 750	Local usage in Butler and Westmoreland counties.

Correlation of drillers' and geologic names of rocks—(Continued).

Name applied by driller, arranged alphabetically not stratigraphically	Geologic horizon: Formation	Geologic horizon: Division	Approximate average interval from Pittsburgh coal to top of bed Feet + = above; — = below	Remarks
Mountain sand (Continued)	Pottsville Pocono	Homewood sandstone Connoquenessing sandstone Burgoon sandstone, upper part	— 950	Local usage in northern Butler County where Pottsville rocks rest upon the Burgoon sandstone.
	Pottsville Pocono	Connoquenessing sandstone Burgoon sandstone	—1,025	Local usage in northern Butler County where Pottsville rocks rest upon the Burgoon sandstone.
	Pocono	Burgoon sandstone	—1,250	General usage; restricted in part to a lower division of the Burgoon in Butler and Westmoreland counties. Same as Big Injun sand.
Murphy sand	Conemaugh	Connellsville sandstone	— 65	Local erroneous usage in Fayette and Greene counties where the Connellsville sandstone is thick.
		Morgantown sandstone	— 165	General usage.
Salt sand	Conemaugh	Mahoning sandstone	— 525	Erroneous usage in Fayette County.
	Allegheny	Freeport sandstone	— 680	Local usage in Washington County.
		Worthington sandstone Kittanning sandstone	— 750	Usage in Allegheny, Fayette, and Washington counties where the sandstones of the Allegheny formation are thick.
	Allegheny Pottsville	Clarion sandstone Homewood sandstone Connoquenessing sandstone	— 880	General usage in Allegheny, Fayette, and Washington counties; subdivisions may be known from the top downward as First, Second, and Third Salt sand, respectively.
	Pottsville	Homewood sandstone	— 950	General usage in Fayette, Greene, and Washington counties. In Greene County frequently includes Clarion sandstone member of Allegheny formation and may be known as Second Salt sand.
	Pocono	Burgoon sandstone, in part	—1,250	Local usage in Fayette County.
		Squaw sand?	—1,600	Local usage in Fayette County.
		Murrysville sand?	—1,850	Local usage in Allegheny and Westmoreland counties.
Salt sand, First	Allegheny	Worthington (U. K.) sandstone Kittanning sandstone	— 750	Local usage in Greene County.
		Clarion sandstone	— 880	Usage in Allegheny County where member is thick and is confused with Homewood sandstone below.
	Pottsville	Homewood sandstone	— 950	Usage in Allegheny County.
Salt sand, Second	Pottsville	Homewood sandstone	— 950	Usage in Allegheny, Greene, and Washington counties where the Clarion sandstone of the overlying Allegheny formation is shaly or is not differentiated.

Correlation of drillers' and geologic names of rocks—(Continued).

Name applied by driller, arranged alphabetically not stratigraphically	Geologic horizon: Formation	Division	Approximate average interval from Pittsburgh coal to top of bed Feet + = above; — = below	Remarks
Salt sand, Second (Continued)	Pottsville	Connoquenessing sandstone	—1,025	Usage in Allegheny, Greene, and Washington counties where Clarion sandstone of Allegheny formation is absent.
Salt sand, Third	Pottsville	Connoquenessing sandstone	—1,025	Usage where Clarion sandstone is recognized as First Salt sand.
Seventy-foot sand	Pottsville	Connoquenessing sandstone	—1,025	General usage in Allegheny and Butler counties where the Connoquenessing sandstone is about 70 feet thick.
		Homewood sandstone	— 950	Local usage in Allegheny and Butler counties where the Homewood and Connoquenessing sandstones are confused.
	Pocono	Burgoon sandstone, upper part	—1,100	Usage in Butler and Westmoreland counties. May or may not include Connoquenessing sandstone member of overlying Pottsville formation.
	Loyalhanna limestone		—1,225	Usage in Allegheny and Westmoreland counties.
Sixty-foot sand	Allegheny	Clarion sandstone	— 880	Local usage in Allegheny and Butler counties; sometimes includes the underlying Homewood sandstone.
	Pottsville	Homewood sandstone	— 950	General usage; sometimes used to include the underlying Connoquenessing sandstone member.
	Pocono	Burgoon sandstone, upper part	—1,100	Local usage in Westmoreland County.
Thirty-foot sand	Pocono	Murrysville sand?	—1,775	General usage in Allegheny and Butler counties. Same as Butler 30-foot sand.
				Erroneous usage in Washington County.
	Catskill	Bitter Rock sand	—1,650	Erroneous usage in Washington County.
		Gantz sand Nineveh sand	—2,025 —2,150	Also called Nineveh 30-foot sand; loose usage in Butler and Washington counties.
		Boulder sand	—2,250	Erroneous usage in Washington County.
White sand	Conemaugh	Saltsburg sandstone, upper part	— 350	Local usage in western Allegheny County.
		Morgantown sandstone	— 165	Local usage in western Allegheny County.

QUATERNARY SYSTEM

ALLUVIUM IN THE ALLEGHENY-OHIO VALLEY

Distribution and Character

For convenience of description all unconsolidated deposits—silt, clay, sand, gravel, and local rock debris—which cover the rock floors of the present valleys below high water level are classed as alluvium. No distinction is made between materials of local and distant origin, even though there is little doubt that in the Ohio-Allegheny valley a considerable portion of the Wisconsin valley train remains undisturbed and buried beneath a thin cover of Recent alluvium of mixed derivation. So little can be ascertained about the detailed characteristics of these concealed deposits that it is impossible to differentiate between local and foreign materials.

In harmony with the preceding definition, the boundary of the alluvium is drawn at the edge of the present-day flood plains, irrespective of the fact that at many localities the plain passes by a barely perceptible increase of slope into terrace deposits of glacial material which is identical in texture and composition with the alluvium. The flood plain of the Ohio-Allegheny valley as thus bounded is widest in the vicinity of McKees Rocks, being slightly more than a mile wide at that place. Downstream it ranges from half a mile to three quarters of a mile in width, at least as far as the mouth of Beaver River; upstream it is less than half a mile wide at most places and narrows to a quarter of a mile at the mouth of Kiskiminetas River. This flood plain is much straighter than the low-water stream bed (Pl. I). Near the western edge of the area covered by this report, as at Edgeworth, the flood plain is approximately 720 feet above sea level, (Fig. 17) from which elevation it rises upstream slightly less than 1½ feet per mile. In the vicinity of Natrona, in northeastern Allegheny County, it is 760 feet above sea level.

From the upper surface of the flood plain, the alluvium extends downward to the rock floor of the pre-Wisconsin valley, which at most localities is below the present stream bed. This pre-Wisconsin valley had a flat gradient and its filling, which was wide and flat, coincided approximately with the present flood plain.

Test borings by the Corps of Engineers, U. S. Army, at the Deadman Island dam site on Ohio River near Edgeworth show that the minimum elevation on its rock floor is not more than 644 feet above sea level, although the cross section of only the western half of the old valley was established. (See Fig. 17). Upstream, other test borings show minimum elevations on the rock floor of 697 feet at Sixmile Island, 250 yards below Allegheny River dam No. 2; 680 feet at the south abutment of dam No. 3 at Springdale; 704 feet at dam No. 4; and 677 feet at dam No. 5. Only at dam No. 5, however, did the borings establish complete transverse profile of the old valley. If, however, the pre-Wisconsin valley floor has a uniform slope between the Deadman Island dam and Allegheny River dam No. 5, a gradient of 0.8 foot per mile, presumably its elevation would be 665 feet at

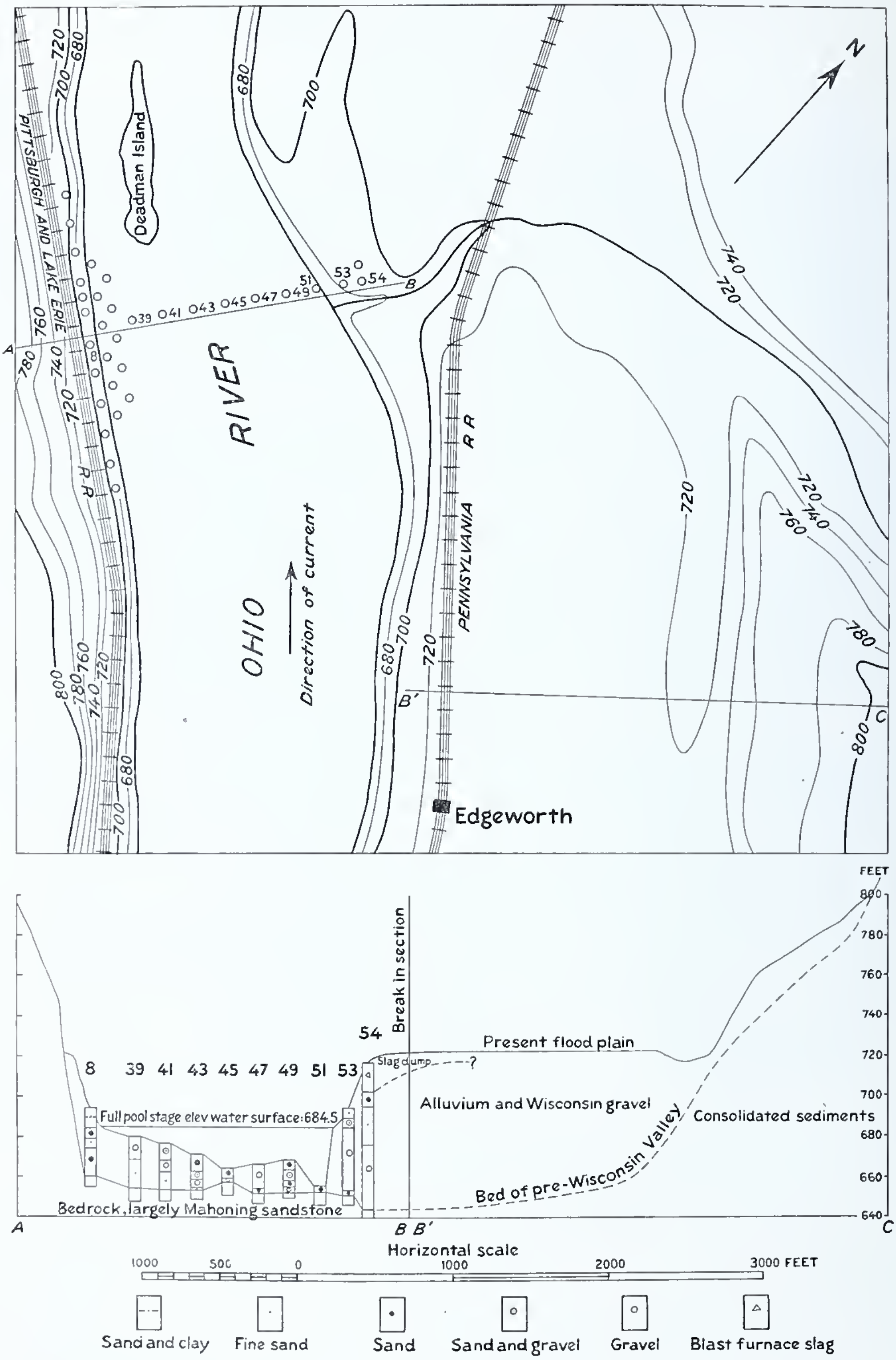


Figure 17.—Topographic map and cross section of the Ohio River valley near Edgeworth, showing relation of the present stream to the pre-Wisconsin valley and the heterogeneous character of the alluvium. Based on test borings at the Deadman Island dam site.

Sixmile Island and 680 feet at dam No. 4. These corollaries are embodied with the measured data in the following representative cross sections of the Allegheny River valley (fig. 18). In most places the

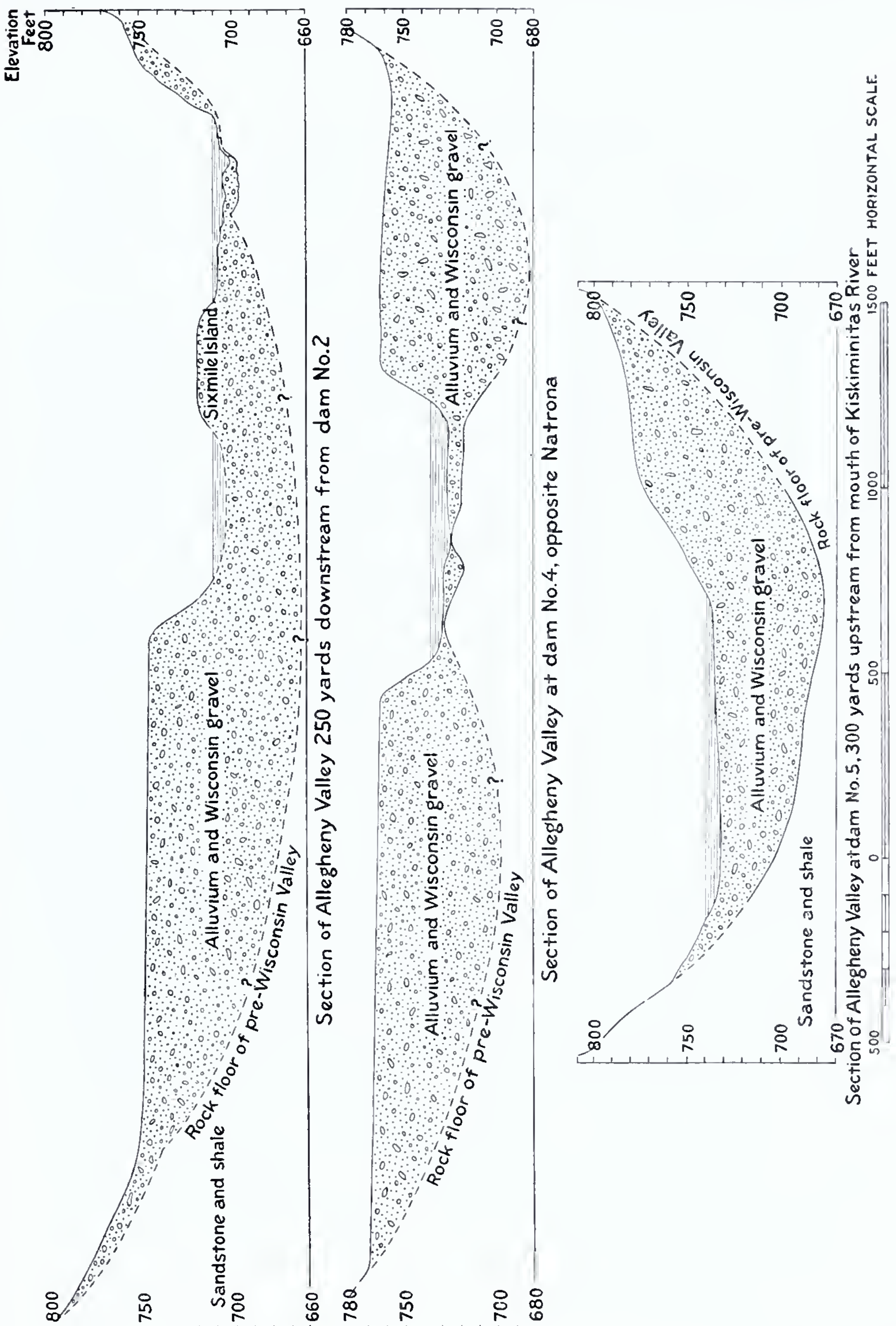


Figure 18.—Approximate cross sections of the Allegheny River valley showing relation of the present stream channel and alluvial flood plains to the pre-Wisconsin valley.

alluvium is as much as 75 or 100 feet thick beneath the flood plains, and from 10 to 30 feet thick beneath the present stream bed. Locally, however, the present stream is flowing over as much as 50 feet of these deposits, and at a few places, as at dam No. 4 (fig. 18), it has carried away the entire alluvial overburden and is flowing on the pre-Wisconsin valley floor.

In developing supplies of water from the alluvium it has been customary in the Ohio-Allegheny valley to locate wells with respect to the present course of the stream. The fallacy of this practice is apparent when it is considered that the distribution and texture of the alluvium is dependent, not upon the present course, but rather upon the less tortuous and broader pre-Wisconsin channel whose limits are approximately those of the present flood plain.

The alluvium of the Ohio-Allegheny valley is a heterogeneous assemblage of unconsolidated gravel, sand, and silt of both distant and nearby origin, in which pebbles of crystalline rocks transported by glaciers from points as far north as Canada are mingled with other pebbles derived locally from resistant sandstones. In the finer material, rock flour of foreign origin is interspersed with local silt formed by the disintegration of the Carboniferous shales. The widespread practice of dredging sand and gravel from the river bed for industrial purposes has shown that in the vicinity of Pittsburgh practically all material will pass a 2-inch screen, though a few boulders are encountered. It is shown further that at one spot the alluvium may be uniform-sized sand or gravel from top to bottom but that elsewhere it may be ill-sorted. On the whole, the volume of gravel is about twice that of the sand, but the current practice of screening the alluvium on the dredge and immediately returning the large proportion of undesired oversize to the river bed does not permit accurate determination of the texture of the deposit. Farther upstream, in the Allegheny Valley, the alluvium is less thoroughly sorted than along the Ohio, although there are many local beds of clean sand and gravel.

Although many holes have been drilled into and through the alluvium, little attention has been paid to differences in texture from place to place so that it is not possible to detect a geographical variation in its water-bearing properties. Hice [59] has stated that on the Ohio and Beaver rivers, west of the area covered by this report, the material at the bottom is prevailingly fine silt which gives place to successively coarser beds above to the top of the present terrace. On the other hand it has been held that at Pittsburgh, the coarsest material is found at the bottom and that overlying beds are progressively finer toward the surface. Over a large portion of the present stream bed, the topmost member of the alluvium is a layer of very fine silt as much as eight feet thick but this is probably to some extent transitory and is probably scoured by freshets and deposited anew as the flood stages decline. The test borings at the Deadman Island dam site on Ohio River, however, of which a portion are shown by Figure 17, do not establish a progressive change in texture from top to bottom of the alluvium.

Rather, they show very marked and seemingly erratic differences in texture from boring to boring as one crosses the valley and similar

[59] Hice, R. R., The inner gorge terraces of the upper Ohio and Beaver rivers: Amer. Jour. Sci., 3d ser., vol. 49, pp. 112-120, 1895.

but less pronounced differences parallel to its course. Actually the alluvium is an assemblage of overlapping and interfingering lenses and pipes each of which may grade laterally from fine silt to gravel. Certain of these in any one boring are made up of uniformly sized particles; others are heterogeneous, with pebbles embedded in a dense matrix of sand and clay.

Occurrence of Ground Water

The alluvium of the Allegheny-Ohio valley is by far the most productive water-bearing formation of southwestern Pennsylvania. Being an aggregate of interfingering lenses whose constituent particles range widely in size, the alluvium may differ greatly in succession and texture of beds and in water-yielding capacity at two adjacent well sites. However, a yield of 200 to 600 gallons per minute may be expected from a well in a good location, the controlling factors being: first, a sufficient thickness of alluvium below the water table; second, the presence of silt-free beds in sufficient thickness; third, an adequate and thoroughly-executed method of well construction. In many places the real estate value of the well site becomes an important consideration.

The lower portion of the alluvium is normally saturated with ground water approximately to the level of the surface stream, although a strict concordance of levels is not to be expected during or immediately after a period of heavy rainfall on the flood plain or a rapid rise of the river. Also, the water table in the alluvium undoubtedly has an appreciable slope toward the river during the prevalence of a stable condition, although the magnitude of this gradient was not established by the investigation. For problems of well location, however, the level of the water table may without much error be assumed to be that of the surface stream.

A sufficient thickness of alluvium below the water table is probable if the prospective well site is not close to either bank of the pre-Wisconsin valley as outlined by the rock bluffs or gravel-veneered rock shelves which bound the present flood plains. It may be known from the logs of nearby wells or excavations, or it may be ascertained directly by test drilling. In the vicinity of Pittsburgh, many borings and excavations have been sunk through the alluvium, probably in sufficient number to establish rather thoroughly the contour of the underlying rock floor. Unfortunately the records of these operations have not been systematically preserved and it was not feasible, in view of the necessary rapidity of the investigation, to collect and correlate these data. Given such data, however, it would be possible to select a prospective well site with the assurance that an adequate thickness of alluvium were present, without recourse to test drilling.

The presence of beds of sand or gravel in the alluvium may be known in a general way from the records of nearby developments, but usually it is not known with certainty in the absence of test borings at the well site. It cannot be too strongly urged that every extensive development of water in the alluvium be preceded by exploratory drilling at a sufficient number of points to establish adequately the local texture and persistence of the possible water-bearing beds. In any such exploratory program the greatest number of borings should be located along a line transverse to the axis of the pre-Wisconsin valley, irrespective of the present stream course, in order to locate the greatest

thickness of coarse material. The technical problems of well construction in the alluvium have been discussed at some length on previous pages.

Several hypotheses as to the origin of the water stored in the alluvium are current in southwestern Pennsylvania. Most common perhaps is the belief that the source lies wholly in the surface stream and that water passes from the river bed into the alluvium within a very restricted area in the immediate vicinity of a well which is being pumped. On the other hand it is widely held that no part of the water in the alluvium comes from the surface stream, but that all has a remote source on the glacial outwash plain south of Lake Erie or on outcrop areas of permeable Carboniferous sandstones which are cut through by the pre-Wisconsin valley. H. C. Kneeland, chemist of the Ohio Valley Water Company, has conducted a painstaking and extended investigation of the problem, from which he has drawn three significant conclusions: first, the water from the alluvium and that from the surface stream differ in chemical composition; second, the water table in the alluvium follows the changing stages of the stream; third, the water table shows a response to local heavy rains and protracted droughts. The difference in chemical composition of the two waters is also discussed in a following section dealing with the quality of the water in the alluvium (pp. 116-121). This difference is greatest in the areas of intense industrial development, in which the surface streams are at times grossly polluted by trade wastes, and shows that any water pumped from the alluvium is not drawn directly from the stream bed in the immediate vicinity. The current alternative hypothesis of the origin of the water, however, must be somewhat modified.

The water which is stored in the alluvium percolates downstream in the normal manner of a valley underflow although at a rate which is presumably a very small fraction of the velocity of the surface stream. Its source is divided. By far the major portion is probably derived from local precipitation on the flood plains, many square miles of which have no surface drainage. Under such conditions all rainfall is absorbed into the alluvium and, if the precipitation is heavy and long continued, a large portion reaches the water table and is added to the ground water storage. A minor portion of the water may come from rainfall on the glacial outwash plain, a part of which percolates downward to the water table and thence into the valley trains of the Allegheny River headwaters. Probably some ground water is discharged into the alluvium through the pre-Wisconsin valley floor from permeable members of the Carboniferous rocks, although this source is presumably relatively small.

The water of the alluvium and the water of the surface stream are not, however, two wholly distinct bodies, because they are separated only by the somewhat transitory layer of fine silt which forms the stream bed. This silt presumably restrains rather than prevents percolation. Given a stable low or medium stage of the river, the water table beneath the flood plains presumably slopes downstream and toward the axis of the valley from either side and the water percolates slowly in the same direction. A small portion of the ground water probably escapes into the surface stream where the restraining silt blanket is thin. Given also local heavy precipitation on the flood

plains, the water table gradient toward the axis of the valley would be increased and percolation in that direction accelerated. The ground water thus transmitted to the stream bed probably constitutes a considerable portion of the dry-season surface flow. This conclusion is substantiated by Kneeland's demonstration that the chemical composition of the river water at extremely low stage approaches that of the ground water. During a freshet, the crest of which usually passes Pittsburgh from 36 to 72 hours after the beginning of regional precipitation, the river stage rises rapidly above the water table, the ground water gradient is reversed, and it is likely that there is some percolation downward and laterally into the alluvium.

Whenever a well located close to the river's edge and entering the alluvium is pumped vigorously the draw-down or local depression of the water table tends to set up percolation downward into the alluvium, the hydraulic gradient created being many times that which suffices for the normal transverse movement into the surface stream during the season of low water. It is probable, therefore, that the yield of such a well does represent in some part water which is drawn from the surface stream in the immediate vicinity of the well. If, however, the layer of silt in the stream bed is thick and if the well is adequately constructed to prevent downward seepage about the casing, it is unlikely that the part so derived is any considerable portion of the whole, even in wells submerged below the river level.

Representative Ground Water Developments

Some of the details of ground water occurrence in the alluvium of the Allegheny-Ohio valley are portrayed by the following descriptions of representative developments, which are given in order as one proceeds upstream.

Edgeworth Water Co. The Edgeworth Water Company's plant (No. 4, Fig. 35) which supplies the boroughs of Edgeworth and Leetsdale (population 4,453[a]) is located on the north bank of Ohio River about 13 miles from Pittsburgh and at the foot of Chestnut Street, Edgeworth. The installation includes nine wells sunk into the alluvium at the water's edge, four of the wells being submerged at normal river stage (controlled) and all being submerged during high water. Their arrangement with respect to the pump station and to the river's edge at normal stage is shown by the sketch (fig. 19). Wells Nos. 1 and 2 were put down about 1900, by driving 10-inch casing into the alluvium about 30 feet below the river bed, the lower 8 feet of the casing being perforated with about 1,400 drilled holes ¼-inch in diameter, spaced 1½ inches center to center. The casings were not cemented or clay-sealed at the top. The wells were finished by sand-pumping until the effluent was clear. Each casing is closed at the top by a reducing flange through which a 6-inch suction pipe with foot valves extends nearly to the bottom of the well, and these suction pipes are joined by 8-inch pipe to a 12-inch suction main which leads to the pump station. Wells Nos. 3 and 4 were constructed in similar fashion in 1915, 12-inch casing perforated at the bottom being driven 35 feet into the alluvium. Wells Nos. 5 to 9 are exactly similar to Nos. 3 and 4. They were put down during August, 1926, and had not been sand pumped and connected to the system at the

[a] 1930 enumeration by Bureau of the Census.

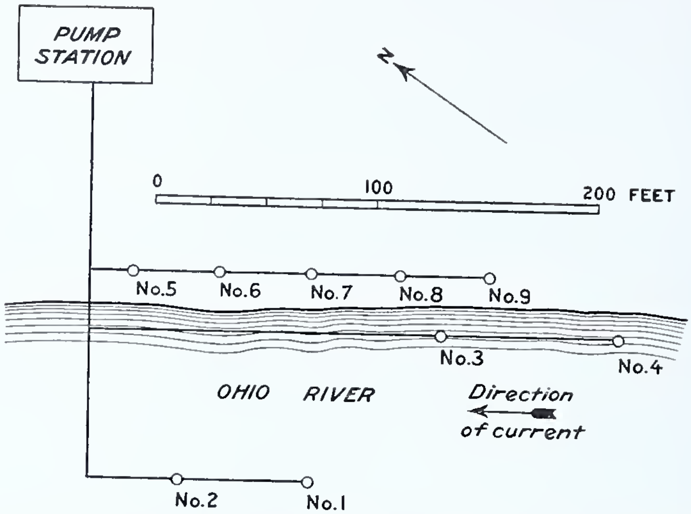


Figure 19.—Sketch plan of Edgeworth Water Co.'s well gang, north bank of Ohio River, 13 miles below Pittsburgh. (No. 4, Fig. 35).

time of the field examination. The bottoms of the wells are approximately 645 feet above sea level and either rest upon the rock floor of the pre-Wisconsin valley or are within a few feet of it. Nothing is known of the texture of the alluvium penetrated except that it is "sand and gravel."

The pumping equipment includes three triplex force pumps with rated capacities of 925 gallons per minute, 350 gallons per minute, and 200 gallons per minute, respectively, each being driven by a gas engine. Water is pumped through the distribution system to two equalizing reservoirs, joint capacity 650,000 gallons, on a river terrace remnant a mile north of Edgeworth at an elevation of 915 feet. Wells Nos. 1 to 4 are pumped at the joint rate of 835 gallons per minute for 7½ to 10 hours daily, the consumption being 380,000 to 500,000 gallons per day. The lowering of the water surface in the wells during pumping, or the drawdown, has not been observed. None of the wells has shown a noticeable decline in yield during its life, additional wells being necessitated by the progressive increase in suburban population.

The water had a temperature early in November, 1926, of 57°F., but during mid-summer it may reach 65°F. Its chemical composition is shown by the analysis, page 70.

Filter cribs. The Sewickley municipal water works, located at the north bank of Ohio River a few hundred feet downstream from dam No. 3, derives its supply from a large L-shaped filter crib. Several other municipalities in the Allegheny-Ohio valley employ similar devices. This type of intake is usually constructed by sinking a pit into the alluvium of the stream bed, facing it with a "cribbing" of 2-inch planks laid flat and spaced two inches apart, back-filling with screened gravel, and covering the whole with a protective layer of fine material. The type of construction insures a very large yield of water derived in part from the alluvium and probably in part from the surface stream, the proportions from the two sources being dependent upon details of construction.

Ohio Valley Water Co. The Ohio Valley Water Co. supplies the boroughs of Bellevue, Ben Avon, West View, Avalon, Emsworth, and McKees Rocks (total population 45,567), as well as Stowe and Ross townships. Its supply is derived from the alluvium and underlying Wisconsin gravels through two groups or gangs of wells, a "main channel" gang (No. 6, Fig. 35) and a "back channel" gang (No. 7) located at the upstream tip of Neville Island about five miles downstream from Pittsburgh. The plan of these two well gangs is shown by a sketch (fig. 20). The wells, all of which are submerged at the

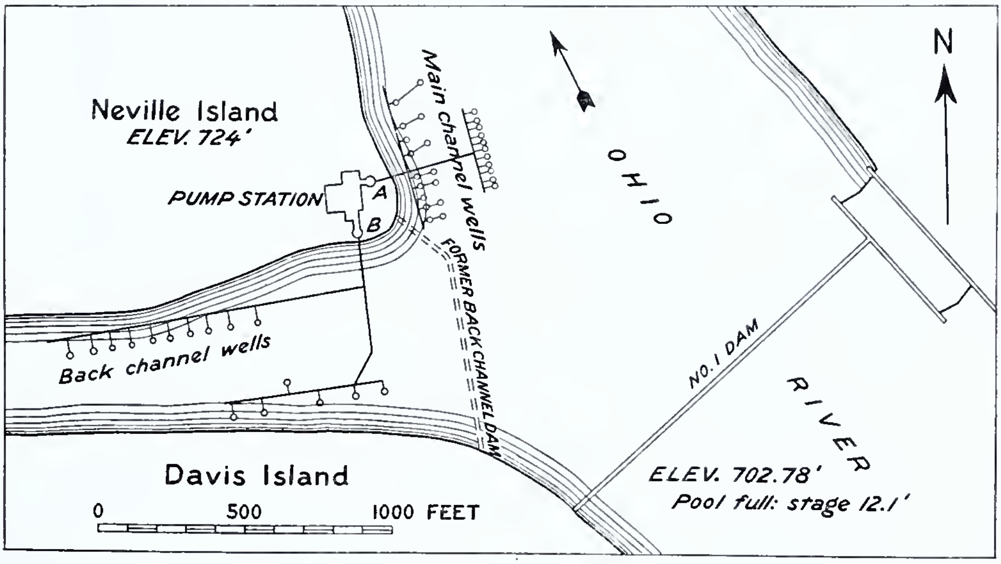


Figure 20.—Sketch plan of Ohio Valley Water Co.'s installation, eastern tip of Neville Island, 5 miles below Pittsburgh. (Nos. 6 and 7, Fig. 35).

normal controlled stage of the stream, are constructed after the common practice of the Pittsburgh district, which is illustrated by the accompanying sketch (fig. 21). Each penetrated about 4 feet of fine

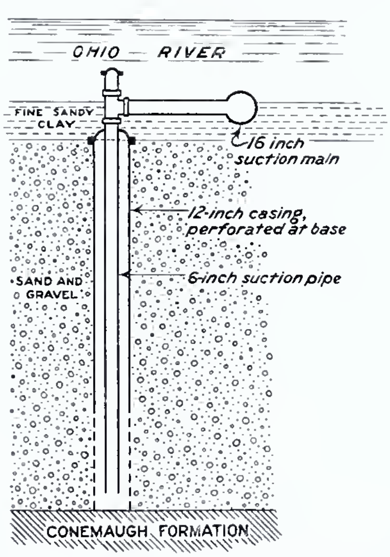


Figure 21.—Diagrammatic sketch showing construction of submerged wells of Ohio Valley Water Co.

sandy silt beneath the river bed, then 35 to 40 feet of sand and gravel, and bottomed on a sandstone member of the Conemaugh formation. A 12-inch casing, of which the lower 8 or 10 feet is perforated with perhaps 1,500 drilled holes ⅜-inch in diameter, extends from top to bottom of the gravel. The top of this external casing is closed by a reducing flange through which a 6-inch suction pipe is extended within two feet of the bottom of the well. At the stream bed, the suction pipe is connected by a tee and a 6-inch nipple 10 feet long to a large suction main. A short flange-closed riser pipe projects upward from the tee and permits inspection of the well when the river is at low stage. The wells of the main channel gang, 28 in number, are joined by a system of suction mains which enters the pump station at the bottom of a pit (A, fig. 20) 54 feet deep. The back channel gang comprises 16 wells, the suction main from which enters an air-tight compartment at the bottom of the back channel pump pit (B, fig. 20). These wells have given excellent service throughout the period of use, although there is some tendency for the perforations of the external casing to become clogged by accretions of calcium carbonate.

The main channel pump pit is equipped with an electrically driven multiple-stage low service centrifugal pump set about five feet below normal river stage and drawing from the wells as a remote intake. A vacuum pump attached to the 12-inch discharge from the low service pump assists the draft during periods when the river stage is below 6.0 feet. In the back channel pump pit a similar low service pump draws upon the air-tight receiving sump below the pit floor, the draft being assisted during low water stages by a vacuum pump attached to the sump. The two low service pumps discharge into an elevated steel tank of 100,000 gallons capacity, which serves a water-softening and chlorinating plant. The softened and sterilized water is raised into storage and pressure reservoirs by three steam-driven high pressure pumps with respective capacities of 1,400, 2,100 and 3,500 gallons per minute. The two reservoirs have respective capacities of 1,700,000 gallons and 6,000,000 gallons. They are located on stream terrace remnants at an elevation of 1,100 feet, one on either side of Ohio River.

Of the total daily consumption of 3 to 4½ million gallons, the two well gangs supply approximately equal portions, each group of wells being pumped at the constant rate of 1,500 to 1,600 gallons per minute for 18 to 24 hours, depending upon the demand. The 28 wells which constitute the main channel gang are encompassed by a space about 250 by 450 feet, and the 16 wells of the back channel gang cover a space about 300 by 1,000 feet. Hence, gross interference between individual wells is highly probable while pumping at the maximum rate. Interference between the two groups, however, is probably slight. Under such conditions it is impossible to estimate with accuracy the potential yield of a single well.

At present the controlled river stage is the same over both well gangs. Formerly, however, the back channel between Neville and Davis islands was spanned by a dam which separated the two gangs. This dam and others were manipulated in such a way that when the river stage at No. 1 dam (see fig. 20) was below 7.0 feet, the back channel was dry and its wells exposed; between stages of 7.0 and 9.2 feet both well gangs were submerged although the back channel stage was as much as six feet

below that of the main channel; for all stages of more than 9.2 feet the back channel dam was topped and the two gangs were submerged to the same level. Under these conditions, Kneeland noted in an observation well sunk through the floor of the main channel pump pit (A, fig. 20), that the static level of ground water was an approximate mean of the stages in the two river channels, and that it responded rather quickly to abrupt changes in river stage. It represents, therefore, a normal hydraulic gradient between the two bodies of surface water, the permeability of the alluvium and the flexibility of the layer of silt just beneath the stream bed permitting a free transmission of hydrostatic pressures. The drawdown while pumping both well gangs at capacity was approximately 7 feet at the observation well, 80 per cent thereof taking place during the first hour of pumping and a stable condition being attained only after six hours. The rate at which the water level rises after the pumps are shut down is approximately the reverse of the rate of drawdown, the level failing to return to normal ground water stage by 0.4 to 0.6 foot during the normal daily shutdown of four hours. If the assumption be made that the main channel well gang is equivalent to a single circumscribing well, the drawdown noted at the observation well indicates a specific capacity for the group of approximately 150 gallons per minute for each foot of drawdown.

The chemical nature of the water obtained by the Ohio Valley Water Co. is shown by analyses (p. 70), and is discussed on pages 118 and 119.

Developments at Pittsburgh. A well (No. 9, Fig. 35) drilled in the yard of the Pennsylvania Drilling Co., Carson Street, Pittsburgh, penetrated 67 feet of alluvial sand and gravel. Its potential yield is more than the maximum demand made upon it. Although located close to the rock bluff which marks the edge of the pre-Wisconsin valley of Ohio River, the well site is in the mouth of Sawmill Run, an alluvium-filled tributary valley, a fact which assures it a sufficient thickness of alluvium below the water table.

Many wells have been sunk into the alluvium in the commercial section of Pittsburgh, a triangular tract whose apex separates the Allegheny and Monongahela rivers. Most of the wells drilled along Allegheny River northwest of Liberty Avenue have been successful, but farther to the south and east the sedimentary rocks of the Conemaugh formation project above the water table so that wells in the alluvium are not successful. Many office buildings within the favorable area possess individual wells and water supply systems. The total pumpage in this district is probably several thousand gallons per minute but the data available are not adequate to estimate the amount exactly. It is reported that the temperature of the water from these wells ranges from 64° to 68°F. during the summer months.

The H. J. Heinz Co. (No. 8, Fig. 35) has a Layne gravel-wall well 30 inches in diameter, which yields 400 gallons per minute to an electrically driven turbine pump. The total depth of the well, the distance from the surface to the static ground water level, and the drawdown during pumping are not known. The alluvium of this locality is extremely heterogeneous and contains a large proportion of sandy and pebbly clay so that thorough test drilling is a prerequisite of any extensive development. Such conditions are prevalent along the north side of Allegheny River east of the confluence of that

stream with the Monongahela, probably as a result of the overburdened glacial stream dropping a large portion of its fine debris in slack currents above the point of confluence.

Springdale municipal water works. The boroughs of Springdale (population 4,781,) Colfax, and Cheswick (1,053), in eastern Allegheny County, derive a municipal supply from three wells (No. 5, Fig. 35) at a site approximately 200 yards north of Allegheny River and on the flood plain of that stream. Wells Nos. 1 and 2 were drilled in 1919 and in 1921 respectively. Each is 64 feet deep, bottoms on the solid rock of the pre-Wisconsin valley floor, and is finished with 10-inch casing of which the lower part is perforated with 2,000 drilled holes ⅝-inch in diameter. The casings are not closed at the bottom. Each of these wells is pumped by an Erb double-acting deep well force pump, power being supplied by a 10-horsepower electric motor through a gear driven Gould pump jack, and yields 130 gallons per minute with a drawdown of 2 feet. This is equivalent to a specific capacity of 65 gallons per minute for each foot of drawdown. Wells Nos. 1 and 2, are now used only for standby or emergency service.

Well No. 3 was drilled during October, 1925, at a site which is 40 feet and 100 feet from the other two wells. This well is 66½ feet deep and is finished with 12-inch casing which is closed at the bottom with a lead packer. Integral with the casing is a Cook screen 25 feet long and 12 inches in diameter, with slot-shaped openings 0.040 and 0.060 inch wide. This is set with its top 23 feet below the surface. The driller's log of the well follows.

Driller's log of Springdale municipal well No. 3.

	Thickness	Depth
	Feet	Feet
Soil	3	0–3
Brown sand, small proportion of gravel	37	3–40
Gravel, fairly clean, maximum diameter of pebbles 2 inches	14	40–54
Sand and gravel intermingled, bed of pea-size gravel at 57 feet	9	54–63
Yellow clay, sand, and gravel	1½	63–64½
Solid rock (shale of Conemaugh formation)	2	64½–66½

The well is equipped with a Cook double acting force pump of 350 gallons per minute capacity, driven by a 10-horsepower electric motor. The static level of the ground water during October, 1925, was 30 feet below the surface, being approximately equal to the mean stage of Allegheny River. Barring a mechanical breakdown or other emergency, well No. 3 supplies the total daily demand of 185,000 gallons by pumping 8 to 10 hours at the rate of 340 gallons per minute. For this draft the drawdown is reported to be slightly less than 3 feet, which is equivalent to the rather large specific capacity of 115 gallons per minute for each foot of drawdown.

The chemical character of the water is shown by the analysis, page 70.

Developments at New Kensington. The United States Aluminum Company, at its Arnold plant on the east side of Allegheny River and half a mile upstream from the highway bridge at New Kensington, has a Layne well (No. 21, Fig. 40) 18 inches in diameter and 85 feet deep. This was drilled in September 1924. A generalized log follows:

Log of well at Arnold plant, United States Aluminum Co.

	Thickness	Depth
	Feet	Feet
Soil and fill at top, mingled sand and gravel at base	70	0–70
Tightly cemented gravel	5	70–75
Sand and gravel	10	75–85
Solid rock	--	85–

The 18-inch casing is landed on the solid rock at the bottom of the well but is not clay sealed at the top. The lower 18 feet is perforated with about 10,000 drilled holes ⅜-inch in diameter spaced one inch center to center. This is a gravel-packed well, in the construction of which about 10 cubic yards of half-inch screened gravel was inserted about the perforated casing to replace the fine material removed by vigorous pumping. The pump is a Layne 7-stage deep well turbine with rated capacity of 600 gallons per minute, its intake being set 80 feet below the ground. The static level at the time of drilling was approximately 40 feet below the surface, and was approximately equivalent to normal river stage. While the well was being pumped at the rate of 520 gallons per minute during a 10-hour capacity test the water level stood about 75 feet beneath the surface, thus indicating a drawdown of 35 feet and a specific capacity of 15 gallons per minute for each foot thereof. The well is now pumped steadily at the rate of 300 gallons per minute to supply cooling water in the foil mill. During November, 1926, the water temperature was 56°F. The nature of the water is shown by analysis and discussion on pages 71 and 116.

At the plant of the National Lead & Oil Company of Pennsylvania, half a mile south of the highway bridge at New Kensington, is a dug well (No. 22, Fig. 40) 55 feet deep and 10 feet in diameter. This is reported to penetrate fine sand to a depth of 20 feet below the surface and extend 35 feet deeper through gravel whose individual cobbles are not more than 3 inches in diameter. The walls and bottom are both faced with brick masonry, approximately 30 inlet ports for the admission of water being created by the omission of a corresponding number of bricks from the lowest course of the side walls. The well is equipped with a duplex steam-driven pump with rated capacity of 250 gallons per minute, although the draft is restricted to 80 gallons per minute. Static level is reported to be 32 feet below the surface of the ground, and the drawdown 20 feet additional while pumping at the test rate of 200 gallons per minute. This corresponds to a specific capacity of 10 gallons per minute per foot of drawdown, although the restricted inlet area undoubtedly causes this to be less than normal.

ALLUVIUM IN THE MONONGAHELA AND YOUGHIOGHENY VALLEYS

Distribution and Character

The alluvial deposits of the major streams of the non-glaciated area, the Monongahela, Youghiogheny, and Kiskiminetas rivers, differ from those of the Allegheny-Ohio valley in being thinner, finer, less assorted according to size of particles, and entirely of local derivation. In the Monongahela valley the average gradient of the surface stream and flood plain is slightly less than 0.5 foot per mile as far upstream as Brownsville, but increases to about 1.5 feet per mile for the portion

between Brownsville and the State boundary line. The rock floor of the pre-Wisconsin valley, however, has a slightly less mature profile, with an average slope of 0.7 foot per mile below Brownsville and 2.0 feet per mile farther upstream. In the lower portion of the valley, particularly between McKeesport and Clairton, the alluvium is between 60 and 90 feet thick beneath the natural flood plains, which locally carry an overburden of waste blast furnace slag as much as 30 feet thick. Upstream the thickness of alluvium decreases and, from the fragmentary data available, seems not to be more than 50 feet at any point above Brownsville. The alluvium which lies beneath the present stream bed is between 7 and 19 feet thick so far as information is at hand. An important factor in the estimation of the thickness of alluvium at any prospective well site is the fact that any meandering stream, such as the Monongahela in portions of its course, cuts laterally away from the center of curvature of a given bend is it deepens its channel. Hence, any broad flood plain or low terrace remnant on the concave bank of a river meander may be in part only a thin veneer of gravel upon a sloping rock base. This condition exists at many places along Kiskiminetas River.

The alluvium of the Monongahela Valley is made up entirely of local debris from the Carboniferous sandstones and shales; the denser and more resistant sandstones form the larger particles, which are in part rather well rounded, and the more abundant shales yield silt and clay. In the vicinity of McKeesport and Clairton the alluvium is made up of alternating beds of sand and clay or of massive gritty clay to a depth of 40 feet below the flood plain. The underlying portion, from 20 to 50 feet in thickness, comprises beds of partly assorted sand and gravel. This gravel contains a small proportion of boulders a foot or more in diameter, but by far the greater portion would pass a 2-inch screen. The detailed texture of the alluvium at points farther upstream is not known.

Representative Ground Water Developments

Duquesne and vicinity. A test well (No. 10, Fig. 35) drilled during December, 1925, in the Union Railroad Company's yard on the west bank of Monongahela River about a mile north of Duquesne had the following log:

Log of Union Railroad Company's test well.

	Thickness	Depth
	Feet	Feet
Granulated blast furnace slag	30	0–30
Soft blue clay	4	30–34
Yellow clay	1	34–35
Sand and gravel	71	35–106

The slag was found to be saturated with water and the sand and gravel of the alluvium yielded water freely. The driller did not note whether the static level of the water in the slag differed from that of the water in the gravel. If the water table is approximately at the level of the river surface, as is presumably the case, it would lie below the layer of clay except during periods of high water. A temporary casing was set and the well pumped by air lift for 10 days or more at an unknown rate for a test of its capacity. It is reported that when

the well was first drilled the water obtained was of excellent quality but that as the test proceeded its hardness increased gradually, amounting to 1,300 parts per million after 10 days' pumping and attaining a maximum of 1,700 parts per million. Four other test wells were drilled with similar results, two being located on the east bank of the river near the end of the railroad bridge and two on the west bank. Inasmuch as the quality of the water developed was not suitable for boiler feed, the test wells were abandoned. The significance of the change in quality of the discharge is discussed further in the sections on quality of water (p. 120).

Duquesne Borough (population 21,396) is supplied by 17 drilled wells (No. 11, Fig. 35) located along the river bank in the northeastern part of the borough. One group of eight wells is located about 15 feet from the low water river's edge and is submerged at high river stages; each is 12 inches in diameter and about 50 feet deep. Of the nine wells located near the pumping station, 100 feet from the low water line, eight are 12 inches and one 10 inches in diameter. The average depth of this group is 65 feet, the wells bottoming at an elevation of about 675 feet and presumably on or close to the solid rock of the Conemaugh formation. All wells are finished with perforated casing. The character of the alluvium penetrated and the distance from the surface to the static ground water level are not known. The wells are pumped by air lifts into a clear water well of 220,000 gallons capacity, from which the water is pumped directly into the distribution system by two Worthington pumps of 1,000 gallons per minute capacity. The maximum aggregate yield from the 17 wells is reported to be 1,900,000 gallons per day, which is equivalent to continuous pumping at the rate of 1,320 gallons per minute. Serious interference between individual wells is probable. The specific capacity of the group is not known.

McKeesport and vicinity. The Tube City Brewing Company of McKeesport has a well (No. 13, Fig. 35) drilled 61 feet deep into the alluvial sand and gravel of the Youghiogheny River flood plain in the southwestern part of the city. It was formerly pumped constantly at the rate of 300 gallons per minute by suction pump; at the present time the draft is from 150 to 170 gallons per minute. The specific capacity is at least 12 gallons per minute for each foot of drawdown.

Seven or eight wells at the McKeesport Tin Plate Co. (No. 15) on the west bank of Youghiogheny River opposite McKeesport are drilled about 60 feet deep into the alluvium. These wells are finished with perforated casing. The group is reported to have an aggregate yield of approximately 1,000 gallons per minute with a drawdown of 12 feet or less, while being drawn upon as a unit intake by suction pump. The specific capacity of the group is, therefore, about 85 gallons per minute for each foot of drawdown. Inasmuch as they are drilled only about 30 feet apart, however, serious interference between individual wells is very probable.

Another representative well (No. 14, Fig. 35) is located at the plant of the United States Glass Co. at Glassport, on the east flood plain of Monongahela River three miles upstream from the mouth of Youghiogheny River. This well is 10 inches in diameter and 74 feet deep and bottoms at an approximate elevation of 665 feet above sea level and probably on or just above the solid rock of the Conemaugh

formation. The well is cased to the bottom with 10-inch pipe, which is perforated between 68 and 73 feet from the surface of the ground with 450 drilled holes ½-inch in diameter spaeed about 4 inches center to center. The well is pumped at a maximum rate of about 25 gallons per minute for glass house service, but the potential yield and specific capacity are both unknown.

Floreffe and vicinity. At the producer gas plant of the Pittsburgh Plate Glass Co. at Floreffe on the west flood plain of Monongahela River, four wells (No. 16, Fig. 35) were drilled into the alluvium in 1921. These are 12 inches in diameter and range in depth from 69 to 73 feet, each reaching solid rock at an elevation of about 680 feet above sea level. Nothing is known of the texture of the unconsolidated material penetrated. Each is cased to the solid rock, the casings being perforated with 500 drilled holes ½-inch in diameter between 1 and 6 feet above the bottom. The static level of the ground water is reported as 38 feet below the surface at the time of drilling. The wells are equipped with force pumps reported to yield 60 to 80 gallons per minute from each. The drawdown while pumping at this rate and the specific capacities are not known.

Another well (No. 18, Fig. 39) located at the Elrama plant of the Equitable Gas Co. in the extreme northeastern corner of Washington County, is drilled through the alluvium to solid rock. The depth is unknown. The 12-inch casing, which is landed on rock, is perforated with ½-inch drilled holes arranged as in well No. 16 described in the preceding paragraph. The well has a reported yield of 100 to 125 gallons per minute although the accompanying drawdown is not stated.

Some prejudice exists among local well drillers against the effectiveness of wells drilled into the alluvium of the Monongahela Valley in the vicinity of Clairton, Elizabeth, and Floreffe. This has led to wells being cased through the alluvium and drilled into the underlying Conemaugh formation, as in the instance of a gang of 74 wells at the by-product coke plant of the United States Steel Corporation at Clairton. On the other hand it is reported that a test well drilled near this location in 1925 entered clean alluvial gravel beneath clay at a depth of about 64 feet and obtained a "large" yield. Furthermore, a well drilled in 1913 near the site of well gang No. 16 at the Floreffe plant of the Pittsburgh Plate Glass Co., which has been described in a preceding paragraph, is reported to have reached the base of the alluvium at a depth of 68 feet and to have had at that depth a maximum capacity of not more than 100 gallons per day. Subsequently the hole was cased through the alluvium and drilled into the Conemaugh formation to a total depth of 144 feet; this well is noted in the tabulated well data (No. 318, Fig. 35). One similar case reported from the lower Youghiogheny Valley is that of a group of wells drilled for the Pittsburgh & Lake Erie Railroad which developed yields of only five gallons per minute from the alluvium and were deepened to the Saltsburg sandstone of the underlying Conemaugh formation. These wells are located near the McKeesport Tin Plate Company's well gang which, it has been pointed out above, yields at the reported rate of 1,000 gallons per minute from the alluvium. Unfortunately, adequate data are not at hand to determine the water-yielding capacity of the alluvium at all points within the district under discussion. It seems, however, that the local adverse sentiment may not be well founded for wells which are constructed according to adequate methods and

are located with consideration for the principles of ground water occurrence in the alluvium. (See p. 103). It is granted that the alluvium of the Monongahela and Youghiogheny valleys is less well assorted in general than that of the Allegheny-Ohio Valley and consequently less uniform in water-yielding capacity; nevertheless it constitutes a productive source of ground water.

Charleroi and vicinity. A group of test wells (No. 19, Fig. 39) in the alluvium was drilled about 1900 at the McBeth-Evans Glass Company's plant at Charleroi on the west bank of Monongahela River in Washington County. It is reported that of eight wells drilled, one yielded water of good quality quite copiously, two entered carbonaceous silt which yielded some gas (presumably methane or "marsh gas") but very little water, and the remaining holes were indifferently successful. Permanent development was deemed inadvisable and the wells were abandoned. No more specific data regarding this test are available. It is regrettable that this exploratory work did not search out the limits of the water-bearing layer encountered in the successful boring, as an adequate basis for estimating the promise of this potential well site.

Nothing is known of the value of the alluvium as a source of ground water in the Monongahela Valley above Charleroi or in the Youghiogheny Valley for more than a few miles above McKeesport. In the upper reaches of these valleys, however, the flood plains become much narrower, especially in the Youghiogheny valley, and, because the rock floors of the pre-Wisconsin valleys have a greater slope than the flood plains, the alluvium thins progressively as the valleys are ascended. Consequently it becomes problematic whether there remains a sufficient thickness of alluvium below the water table to permit successful wells yielding more than a few tens of gallons per minute.

ALLUVIUM IN THE TRIBUTARY VALLEYS

Throughout southwestern Pennsylvania the graded portions of the tributary valley floors, even those of a very inferior order of magnitude, contain alluvial deposits which range in thickness from a few feet up to 25 or 30 feet. This material varies greatly in character and water-yielding capacity. Along the lower reaches of the larger tributaries, whose beds had been deepened to the grade of the master stream during pre-Wisconsin time, the alluvium is similar in texture and value as a source of ground water to that of the master streams. Elsewhere, if the tributary valley drains an area within which coarse-grained sandstone members appear in the Carboniferous sediments, the alluvium may have a high water-yielding capacity by virtue of a large proportion of sandy and pebbly debris. If, on the other hand, the drainage basin is underlain chiefly by shale and limestone the alluvium is usually very fine grained and an inferior water-bearer. In other areas of relatively great relief, as within and along the borders of the Allegheny Mountain district in the eastern part of the area, the alluvium is composed of coarse rock waste and hence may be highly permeable.

The alluvial deposits of the minor valleys are inferior sources of water, their extreme heterogeneity making for lack of uniformity in water-bearing properties and the restricted drainage areas inducing wide seasonal fluctuations in the volume of stored water. They have,

however, been widely developed in the past for domestic and minor industrial uses although they are in almost every case subject to pollution and are not sources of pure wholesome water. Most of these supplies have been abandoned. A few typical developments are described in the succeeding paragraphs.

Well 17 (Fig. 39) owned by Sam Deblasoi, located on McPherson Creek, two miles northwest of Hendersonville, in Cecil township of northern Washington County, was drilled 28 feet deep into alluvium in 1916. The well is finished with 5⅝-inch casing and derives its supply from sand between 5 and 28 feet beneath the surface of the ground. This sand is presumably of local origin and from sandstone members in the lower part of the Washington formation. The static level of the ground water is reported to be at the elevation of the nearby creek and to fluctuate with it. The well is equipped with a suction pump, and yields in ample abundance for domestic needs. The temperature of the water during October, 1926, was 53° F., although a seasonal variation of several degrees is probable. The chemical nature of the water is shown by the analysis on page 70.

At the Daisytown mine of the Vesta Coal Co., West Pike Run township in southeastern Washington County, the miners' dwellings along Pike Run were formerly supplied by a number of drilled wells (No. 20, p. 358; location equivalent to No. 398, Fig. 39) in the gravel of the creek bed. The gravel is derived from the lower part of the Washington formation and the Monongahela formation. These wells were 25 to 30 feet deep, were lined with 5⅝-inch casing from the surface to a depth of 8 to 10 feet, and were equipped with suction and force pumps. In each case the static level fluctuated with the stage of the creek. Each well constituted an adequate domestic supply for several dwellings.

The Sam Kalp residence in Davistown village, Saltlick township of northeastern Fayette County, is supplied by a dug well (No. 25, Fig. 37 and p. 302) 26 feet deep and 4 feet in diameter. This enters alluvium made up of local waste from sandstone members of the lower part of the Conemaugh formation and the massive coarse-grained Pottsville sandstones beneath. The static level is about 20 feet below the surface of the ground during the summer months. The well is equipped with an automatic electrically driven suction pump with capacity of 3 gallons per minute. In November, 1926, the temperature of the water was 56°F. The content of dissolved mineral matter is shown by the chemical analysis on page 71.

QUALITY OF WATER IN THE ALLUVIUM

The water in the alluvium of the Allegheny-Ohio Valley is shown by analyses 4, 5, 6, 7, and 21 (see p. 70 and fig. 22) to be moderately concentrated. Bicarbonate exceeds sulphate in the more concentrated waters, although the relative abundance of bicarbonate is by no means a fixed proportion of the total dissolved solids. The total hardness is high, and ranges between 135 and 350 parts per million when calculated as calcium carbonate ($CaCO_3$). The non-carbonate or permanent hardness is from 60 to 146 parts per million and exceeds the non-carbonate or temporary hardness in sample No. 21. Hence, these waters have large soap-consuming and scale-forming powers, and are not highly desirable as a domestic or industrial supply unless softened.

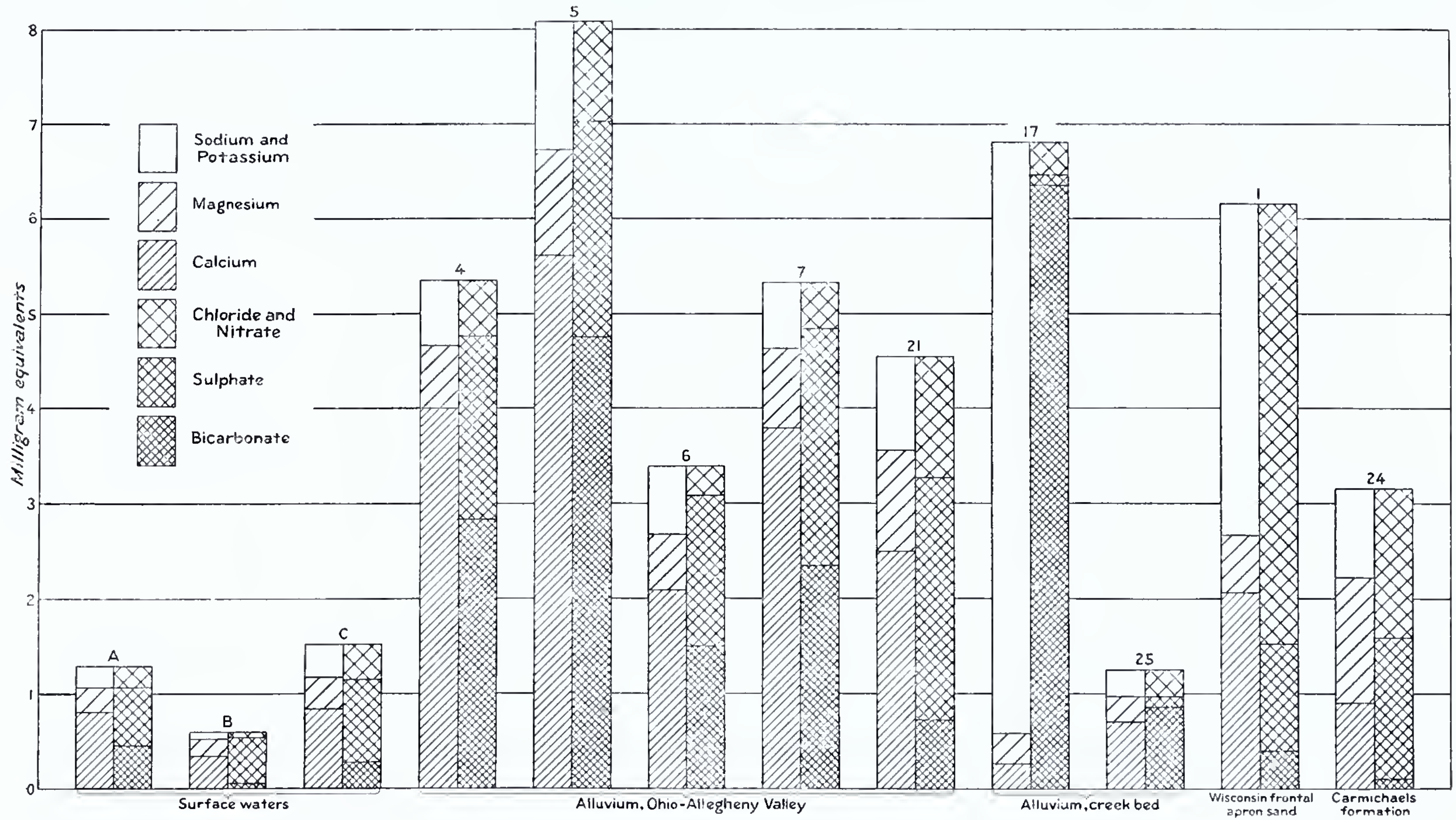


Figure 22.—Chemical character of water from the unconsolidated deposits in comparison with surface waters.

With the exception of sample No. 21, the content of dissolved iron does not exceed 0.17 part per million, a concentration which is not objectionable for any ordinary use.

As an approximate standard of comparison, the quality of the surface waters is shown by three samples which are designated A, B, and C, collected during the first week of November, 1926, while the streams were at a moderately high stage. These three samples were collected during the same period as the samples of water from the alluvium which have been discussed in the preceding paragraph (see p. 71 and Fig. 22).

H. C. Kneeland,[60] chemist of the Ohio Valley Water Co., studied the variation in quality of the water from the alluvium in relation to the quality of the surface waters at some length. This study was made when the Ohio River was so controlled by dams that when the stage at No. 1 dam nearby (see Fig. 20,) was less than 7.0 feet, the back channel well gang was exposed; that between stages of 7.0 and 9.2 feet, both well gangs were submerged, although the back channel stage was as much as 6 feet below that of the main channel; that for all stages exceeding 9.2 feet all dams were topped and both the back channel well gang and the main channel well gang were submerged to the same level. A portion of the data obtained by Kneeland under these conditions is presented graphically by the diagram (fig. 23) which shows that the relative quality of samples C, 6, and 7 (pp. 70-71) holds for a protracted period during which the river stage varies widely. Furthermore, although the hardness of the river water decreases sharply with the freshet which lags about 36 hours behind each period of regional precipitation, the hardness of the ground water does not diminish at the same time. On the other hand, it is true in several instances that the hardness of the ground waters is greatest when that of the surface water is the least. Inasmuch as the greater proportion of the ground water probably originates in rainfall upon the flood plains (see p. 104), its variations in quality should be dependent upon local precipitation. In substantiation of this inference the diagram suggests that the periods of minimum hardness of the ground water lag some 6 to 9 days after the periods of rainfall and 5 to 7 days after the river freshets. Finally, the diagram fails to indicate any definite response of the quality of the water from the back channel wells to periods of low river stage when the wells are not submerged. In view of these relations, as well as the great difference in concentration of the surface waters and the ground water and the chemical dissimilarity between the two, it is clear that the water pumped from wells which enter the alluvium is not drawn directly from the stream as is popularly supposed.

It is reported that excessively hard water has been encountered at several localities in the alluvium of the major valleys. Each of these localities is the site of a former blast furnace about which large quantities of furnace slag have been dumped upon the flood plain, a condition which suggests a genetic relation between slag and hardness of water. To test the soundness of this inference, the solubility of a sample of weathered slag obtained from a trench at the Neville Island plant of the Ohio Valley Water Company, was determined. This slag had been buried about 8 feet below the present land surface and 8 to

[60] Kneeland, H. C., Report on water supply of the Ohio Valley Water Co.; Manuscript report to board of directors, 1920.

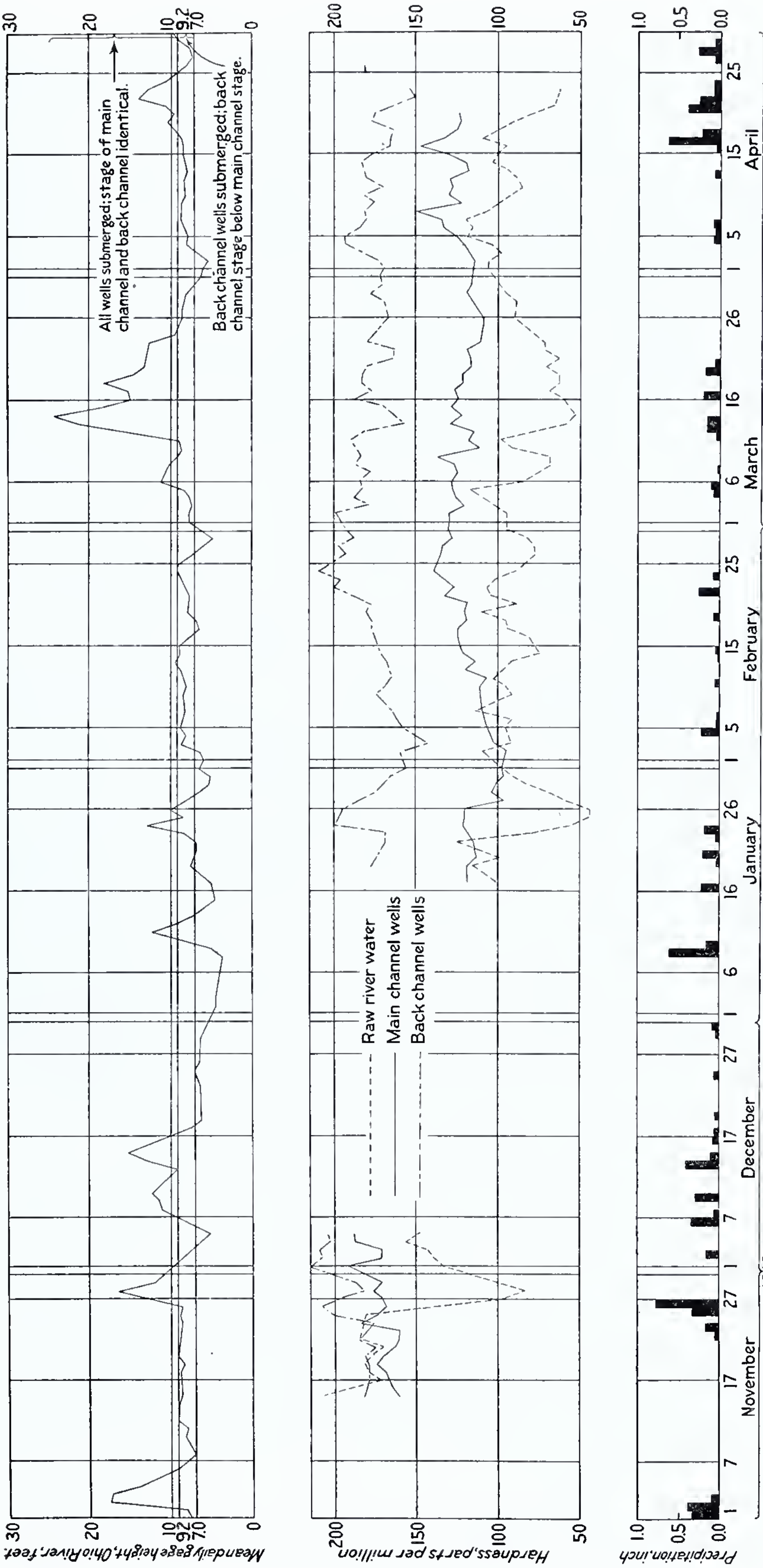


Figure 23.—Relation of hardness in water from Ohio River and from the alluvium to variations in river stage and to local precipitation.

10 feet above the water table for at least 20 years. The sample was crushed in the laboratory to pass a 65-mesh screen, and air dried. A 100-gram portion of the air-dried sample was allowed to stand for 10 days in contact with 1,000 c. c. of distilled water, the whole being shaken occasionally. An equal portion was allowed to stand for the same period in contact with 1,000 c. c. of water which was slightly acidulated with hydrochloric acid. Approximate analyses of the two filtrates at the end of the 10-day period are shown by the following table. This determination substantiates a similar test by Kneeland.[60]

Solubility of weathered blast furnace slag

[Analyzed by Margaret D. Foster, Quantities in parts per million.]

	Distilled water filtrate	Acidulated water filtrate
Calcium (Ca)	250	4,000+
Carbonate (CO_3)	24	.....
Sulphate (SO_4)	400	2,000
Chloride (Cl)	46	
Hydroxide (OH)	19	0
Total hardness, calculated as $CaCO_3$	643	19,275

It is evident from the analyses of the filtrates that a dump of weathered slag is an adequate source of excessive hardness in the ground water of the underlying alluvium. It seems probable that the difference in concentration and quality of the water from the main channel wells and the back channel wells of the Ohio Valley Water Co. (Nos. 6 and 7, respectively, p. 70), is due to matter dissolved from the slag which covers the eastern end of Neville Island and carried down to the water table close to the back channel wells.

The marked increase in hardness of the water during the 10-day pumping test of the trial wells of the Union Railroad Co. in the vicinity of Duquesne (No. 10, Fig. 35, also p. 112) may be due to a constantly increasing influx of hard water from the slag to softer water which is normal to the underlying alluvium. It is probable that the water contained in the slag at the site of well No. 10 is normally restrained from mingling freely with the water of the underlying gravel by the intervening bed of clay, for the difference in head between the water in the slag and that in the gravel can not be large. It is not unlikely that this clay bed was so much disturbed by the drilling that water could percolate downward from the slag around the casing. Under these conditions the rate of percolation might increase throughout the pumping test as the cone of depression was deepened. If the well casing had been carefully sealed through the slag and through the underlying clay (see pp. 42-45) downward percolation of water from the slag would have been prevented and the increase in hardness of the water minimized. It would seem that adequate casing of all wells which pass through such slag dumps into the underlying alluvium might produce a considerable improvement in the quality of the water developed.

Although at most places the water from the alluvium does not contain a large quantity of dissolved iron, sample No. 21 (p. 71) con-

[60] Kneeland, H. C., op. cit.

tains 108 parts per million of this constituent. The presence of so much iron in solution renders a water unfit for any ordinary purpose. In this case unlimited use of the water for general mill service is impossible on account of the large volume of iron oxide sludge which is deposited in pipes and drains. It is reported that the iron content of the water when the well was first placed in operation in September, 1924, was 6 parts per million (expressed as Fe_2O_3); also that by June of the following year it had increased to 60 parts per million and by May, 1926, to 124 parts per million. The sample whose analysis is tabulated on page 71 was collected in October, 1926. Although several other wells in the New Kensington area obtain ground water from the alluvium, none are reported to have an objectionable iron content. At the Firth-Sterling Steel Company of McKeesport, in the lower Youghiogheny River valley, the water in the alluvium also contains a large content of iron. Aeration of the water has been found effective in conditioning it for use. Such iron-rich waters are distinctly anomalous in the alluvium and no adequate explanation is at hand. Whether they are genetically related to trade wastes, either buried beneath the present land surface or dischargd into the surface streams, is not known.

The range in the quality of the water from the alluvium of the minor valleys is suggested by samples from wells No. 17 and No. 25 (pp. 70-71 and fig. 17). Sample No. 17 is a moderately concentrated water with a concentration of 382 parts per million. The sodium and potassium (Na+K) ions constitute 45 per cent of the total dissolved solids as measured by reacting value, and the bicarbonate (HCO_3) ion makes up 43 per cent. Hence the water is very soft, its calculated hardness being 29 parts per million. Such a water is a moderate soap-consumer and scale-former, though it would foam in a troublesome manner if used for boiler feed. Sample No. 25 on the other hand is a slightly concentrated water which contains 83 parts per million of dissolved solids. Calcium is 28 per cent of the dissolved solids as expressed in reacting value, whereas bicarbonate (HCO_3) is 17 per cent and sulphate (SO_4) is 16 per cent. The soap-consuming constituents sum up to 47 parts per million when calculated as calcium carbonate, so that the water is only moderately hard.

LATE GLACIAL (WISCONSIN) GRAVEL

Valley train and stream terrace deposits

Along the Allegheny-Ohio valley the alluvial flood plain merges landward with undisturbed glacial gravel of Wisconsin age, the cartographic boundary between the two units being drawn at the increased surface gradient which marks the limit of stream overflow. Most of the pebbles and boulders, which are well-rounded and form the most impressive part of the deposits, are between one and three inches in diameter, although the largest are about 18 inches in diameter. These pebbles are composed of quartz, quartzite, granite, sandstone, and some limestone, the crystalline rocks being of distant origin from New York and Canada. They are well rounded by water and, excepting the limestones, show little if any effect of weathering. All the pebbles are embedded in a matrix of sand and clay, and even in the coarsest phases of the material much of the interstitial space is occupied by fine particles.

The largest area of Wisconsin gravel occurs in the southern part of the borough of Allegheny, or Pittsburgh North Side, in which locality it extends approximately up to 820 feet altitude and forms a low terrace three quarters of a mile wide. The formation is quite generally present along both sides of the river and though commonly narrow it widens locally to half a mile or more. It is rather difficult to differentiate the low terraces along the Ohio Valley because some of them seem too high to be contemporaneous with the lastest glacial activity. The most extensive, however, which for the most part lie below the 800-foot contour, are regarded as of Wisconsin age. Munn[61] has pointed out the possibility that the gravels on these rock terraces, at elevations of 760 to 810 feet, were deposited during the time when the Ohio was deepening its valley, prior to the influx of Wisconsin material.

The Wisconsin stage is probably represented in the Monongahela and Youghiogheny valleys by certain low river terraces which merge upstream with the present flood plain. However, none of the terraces of these valleys contain ice-borne debris of distant origin so that precise differentiation is impossible.

The Wisconsin gravels and terrace deposits, exclusive of the beds which underlie the river flood plains and are described as alluvium, are not highly productive sources of ground water. Without known exception, they are subject to drainage down to the level of the flood plain water table. In a large part of its outcrop area at least, these deposits are about 15 feet thick and rest upon a sloping rock base which constitutes a flank of the pre-Wisconsin valley floor. For example, the extensive sloping terrace between 740 and 780 feet above sea level on the north side of Ohio River at Sewickley is a gravel-covered rock shelf. So also is the terrace at approximately the same elevation at Shousetown on the south side of the valley.

Under such conditions the Wisconsin gravel does not extend downward to the level of the flood plain water table and consequently it does not retain ground water. Small bodies of ground water may be perched within the formation, being upheld by local beds of impermeable clay, or may exist intermittently in areas within which the downward drainage is retarded. Such bodies of water, however, even if developed, could not be expected to supply a continuous draft of more than a few gallons per minute.

Frontal apron deposits

In northern Butler County, in the vicinity of Harrisville and Slippery Rock, a few fingers of glacial outwash from the serrate front of the Wisconsin moraines enter the region from the northwest. These deposits form broad flats between 1,260 and 1,340 feet above sea level. In places the outwash deposits are moderately well bedded and consist of layers of sandy clay, angular iron-stained quartz sand, and well rounded pebbles. The sand, which is by far the most abundant constituent, is usually rather well sorted, most of the grains being about 1 millimeter (one twenty-fifth inch) in diameter. The pebbly layers usually contain much sand and present a wide range of sizes up to abundant pebbles half an inch in diameter with a subordinate

[61] Munn, M. J., Description of the Sewickley quadrangle: U. S. Geol. Survey Geol. Atlas, Sewickley folio (No. 176), p. 7, 1911.

proportion of small cobbles from 2 to 4 inches in diameter. Much of the material seems to be of local origin. The formation has been exposed in sand and gravel pits to as much as 20 feet below the surface, although its base is not disclosed at any point. Its maximum thickness is certainly much greater, perhaps of the order of 50 feet.

The sand and gravel beds in the frontal apron deposits, at least within the comparatively small area in Butler County within which they were deposited, contain much shallow ground water. At no place, however, have they been developed beyond the needs of domestic consumption so that the ultimate water-yielding capacity can not be estimated. It should be borne in mind, however, that the purity of any water stored in such unconsolidated material close to the surface is liable to pollution by objectionable organic waste, unless the water-bearing member is overlain by a protective layer of impermeable clay.

A typical well in the frontal apron deposits is that of the Cathcart Hotel in Harrisville (No. 1, Fig. 36 and p. 272), which is supplied by a dug well 14 feet deep. It is reported that this well penetrated 12 feet of fine sand which yields water very slowly, and then encountered a 2-foot bed of clean water-bearing gravel of half-inch size. The draft, which is by suction pump, is probably not more than a few hundred gallons per day. No seasonal fluctuation in static level or in yield has been noted. The greater part of the household water supplies in the community are obtained from the same bed of gravel through dug or driven wells.

The chemical character of the water from the frontal apron deposits is represented by a sample from well No. 1 (see page 70 and fig. 22, p. 117). This water is moderately concentrated and contains 397 parts per million of dissolved solids. It has a total calculated hardness of 136 parts per million, of which the noncarbonate or "permanent" hardness amounts to 117 parts per million. Hence, its soap-consuming and scale-forming powers are moderately high. The large content of chloride (Cl) and nitrate (NO_3) suggests that this shallow body of ground water is polluted by objectionable organic wastes.

INTERMEDIATE GLACIAL GRAVEL

In the Ohio River valley below Pittsburgh, Munn[62] has concluded that the upper portion of the sloping terrace on the east side of Ohio River in the vicinity of Ambridge,* namely that portion which lies approximately between 760 and 810 feet altitude, probably represents a stage of glaciation somewhat older than the Wisconsin but certainly younger than the Illinoian. The sloping terrace at Coraopolis whose top is about 820 feet above sea level, and at the same general elevation on the north side of the valley in the vicinity of Emsworth are also to be correlated with a possible intermediate stage of glaciation. Each of these terraces is covered with a thin layer of ice-borne gravel which is very similar in composition and texture to that of known Wisconsin age.

The bodies of intermediate glacial gravel are not extensive in area or of great thickness. Any water absorbed by them is subject to drainage into bodies of permanent ground water at lower elevations.

[62] Munn, M. J., op. cit.

* Ambridge is located in Beaver County, immediately north of the point at which the boundary of the area surveyed crosses the Ohio River.

unless perched in small volume upon layers of clay. In view of these conditions, the formation does not constitute an important source of water.

EARLY GLACIAL (ILLINOIAN) GRAVEL

Allegheny-Ohio valley train

The early glacial deposits of the Allegheny-Ohio Valley are the remnants of the valley train of debris transported by streams from the outwash plain and terminal moraines of the Illinoian ice sheet. The areas covered by this formation are small and discontinuous, being the rather narrow shelf-like terraces of the Parker strath. These terraces are generally 150 to 300 feet above the present stream within the area studied, the interval decreasing upstream inasmuch as the strath is more nearly horizontal. The present remnants of the formation are generally 5 to 25 feet thick, although local maxima of as much as 50 feet occur in the lower part of the valley and of 90 feet in the vicinity of Templeton, to the east of Butler County. Originally, however, the thickness must have been much greater than even these maxima, for scattered pebbles and patches of gravel are found on the valley sides as much as 130 feet above the strath. In the Ohio Valley these deposits are found between 900 and 1,000 feet above sea level. To the east, however, along Allegheny River, they occur at successively higher altitudes upstream and in the vicinity of Foxburg, near the northeastern corner of Butler County, are from 1,020 to 1,140 feet above sea level. Consequently the general gradient of this old valley train amounts to about 150 feet between Pittsburgh and Foxburg, a distance of approximately 80 miles.

The Illinoian valley train is composed of rather poorly stratified beds of medium or fine gravel and sand. Some boulders of large size are present, and cobbles about 6 inches in diameter are not rare. Elsewhere, the formation is largely clay with a very small proportion of the coarser material. Leverett[63] has estimated that the pebbles and cobbles constitute only a fraction of one per cent of the whole. Most of these pebbles and cobbles are of quartzite, granite, and sandstone of distant origin, which have been so thoroughly rounded by abrasion that no traces of glacial striae remain. The pebbles are in an advanced state of decay and many of those of granite and sandstone are weathered in the very center and can be crumbled in the hand. Those of quartzite and of highly quartzose sandstone, however, are rather well preserved. If pebbles of limestone were ever present in the formation, they have been wholly destroyed. With the boulders and cobbles are mingled gravel, sand, and clay from both distant and local sources.

Most of the remnants of the Illinoian valley train lie upon rock shelves far above the river so that they do not contain a large amount of ground water, especially where they are composed largely of coarse material. Local small bodies of ground water may be trapped, however, in depressions of the rock shelf. Where the valley train contains much clay it may be poorly drained or water may be perched upon an impermeable layer. Under these conditions domestic water supplies of moderate permanence may be obtained from the Illinoian deposits, as at Parkers Landing near the northeastern corner of Butler County

[63] Leverett, Frank, Glacial gravels [of the Kittanning quadrangle]: U. S. Geol. Survey Atlas, Kittanning folio (No. 115), p. 910, 1904.

(No. 2, Fig. 36). In the higher parts of this community, which is built upon the Illinoian terrace at an altitude of 1,100 feet above sea level, there are many dug wells 20 to 30 feet deep in pebbly clay. The static level of the ground water is reported to fluctuate greatly through the seasons. During the summer months, the yield of a single well is barely adequate to the domestic needs of one household.

Carmichaels Formation

During the Illinoian stage of glaciation the aggradation of the Allegheny Valley by glacial gravels blocked the mouths of the tributary streams from the nonglaciated terrane to the south, and caused them to deposit much of their loads of silt.[64] Possibly also, ice jams caused local ponding of these tributaries with consequent deposition of sediments above the barriers, as proposed by Campbell.[65] After the streams had completed their post-Illinoian downcutting, in part in wholly new courses, these sediments remained as a veneer over the rock terraces and abandoned reaches which now constitute the remnants of the Parker strath. Throughout the region, such high terrace deposits as are stream-laid, as are wholly free from ice-borne material of distant origin, and as are contemporaneous with the early glacial valley train, are known as the Carmichaels formation from the type locality in eastern Greene County. It may be noted from the geologic map (Pl. I) that the formation is quite extensive along the Monongahela, Youghiogheny, and Kiskiminetas rivers and along those major tributaries which do not occupy strike valleys of comparatively late origin.

At the type locality of the Carmichaels formation the rock floor of the pre-Illinoian stream has an elevation of about 920 feet above sea level and 150 feet above the present bed of Monongahela River. Beds of clay, sand, and gravel fill the old valley to a depth of 60 or 70 feet and extend up its sides to a height of 160 feet above its rocky floor. The lowest materials are coarse and well rounded, the deposits of an active stream. Above this gravel, the materials range from exceedingly fine and well laminated clay to sand and pebbles borne by strong currents. Large boulders, which probably were rafted by floating ice or tree trunks occur at a few places in the midst of fine materials. About 1½ miles below Carmichaels the valley filling stops abruptly, a phenomenon which Campbell[66] believes to indicate the presence of an ice jam below which the channel was never silted up. Elsewhere along the Monongahela Valley the sediments of the Carmichaels formation are usually very similar to those of the type locality, although about 1½ miles southeast of New Geneva and at other points there are deposits of very fine white clay of pottery grade. The floor of the abandoned ox-bow channel about Bellevernon, in Westmoreland and Fayette counties, is covered with 15 to 20 feet of coarse sand which encloses many boulders, both rounded and angular, as well as lenses of clay. This sand has been used in considerable volume in the past for making glass. The whole is covered by a layer of loess-like clay a few feet thick.

On the whole the Carmichaels sediments of the Youghiogheny Valley

[64] Shaw, E. W., High terraces and abandoned valleys in western Pennsylvania: Jour. Geol., vol. 19, pp. 140-156, 1911.

[65] Campbell, M. R., Description of the Masontown and Uniontown quadrangles: U. S. Geol. Survey Geol. Atlas, Masontown-Uniontown folio (No. 82), p. 9, 1902.

[66] Campbell, M. R., Loc. cit.

are coarser than those of the Monongahela Valley. The terraces about Connellsville in north-central Fayette County, for example, are deeply covered with very coarse gravel which doubtless owes its origin to the sudden decrease of the stream grade at that point as it emerged from its gap through Chestnut Ridge onto the soft rocks of the Kanawha section. Farther downstream, in the abandoned channel about Perryopolis, the lower member of the formation consists of coarse sand similar to that at Bellevernon and is at least 22 feet thick. This is overlain by 14 feet of very fine white clay which has been used for the manufacture of brick. At other localities the material is similar in character, but its softness makes natural exposures few and unsatisfactory.

Extensive deposits of the Carmichaels formation also occur in the Kiskiminetas basin. Most extensive are the broad terraces at an altitude of about 1,040 feet along Conemaugh River between Blairsville and Tunnelton. Others are the terraces along Loyalhanna Creek in the vicinity of Latrobe at an elevation of 1,020 feet, and the broad shelf at the western foot of Chestnut Ridge between Derry and Hillside. Along the Kiskiminetas Valley below the junction of its two tributaries, broad terraces covered with Carmichaels deposits extend from Saltsburg downstream to Avonmore and Salina. Still farther downstream the terrace has been deeply dissected by post-Illinoian downcutting and the remnants are smaller and less continuous. Throughout this district the Carmichaels formation is composed largely of sand and gravel with some lenses of clay and scattered large boulders. In general the material becomes progressively finer towards the west, that is, away from Chestnut Ridge.

The stream-borne Carmichaels deposits do not appear in the Allegheny-Ohio Valley, being replaced by the glacial valley train. Deposits of this formation do appear, however, in some of the tributary streams, as along Brush Creek in southwestern Butler County, on terraces ranging from 940 to 1,000 feet above sea level. In this locality the deposits are usually from 5 to 10 feet thick, and are composed of sand with some clay and pebbles. Some of the pebbles are notably angular. None of the areas covered by the Carmichaels formation on these tributary streams, however, are of mappable size.

The water-bearing properties of the Carmichaels formation vary greatly from place to place in harmony with the variable texture, extent, and position of the deposits. Many of the smaller deposits of the Carmichaels, which lie on exposed terraces, are likely to be completely drained. On the broader terraces and in the abandoned portions of the pre-Illinoian channels, however, considerable bodies of ground water may be held in the sandy and gravelly layers of the formation. With the exception of the gravel covered shelf which lies at the western base of Chestnut Ridge in the vicinity of Derry, these deposits do not receive ground water by lateral infiltration but the sole source is the rain which falls directly upon them. Under such conditions the rate of ground water recharge is not sufficient to meet the demands of a heavy continuous draft, although yields up to 5 or 10 gallons per minute can be developed at favorable sites in many localities. As in the case of all unconsolidated deposits, the sanitary quality of the water is open to suspicion.

A typical instance of ground-water development from the Car-

michaels formation is the well (No. 24, Fig. 38 and p. 320) at the residence of H. J. Williamson, in Mapletown, eastern Greene County. The site lies in an arm of the abandoned channel of Monongahela River at the Masontown ox-bow. The well is dug 26 feet deep by 30 inches inside diameter and lined with dry masonry. Water was encountered from 24 to 26 feet below the surface in a fine well-assorted sand underlying a clayey soil. The static level is normally 24 feet below the surface of the ground and is reported to be free from seasonal fluctuations of notable magnitude. The well is equipped with an automatic electrically driven pump with a capacity of 3 gallons per minute, the yield being adequate to household needs at all seasons.

The only sample of water that was obtained from the Carmichaels formation is that from well No. 24 (see p. 71; also figure 22, p. 117). In this sample the concentration is moderate, but the soap-consuming and scale-forming ingredients are relatively abundant. The total hardness, calculated as calcium carbonate, is 111 parts per million, of which 107 parts are non-carbonate or "permanent" hardness. It contains almost no iron.

CARBONIFEROUS SYSTEM

PERMIAN SERIES (DUNKARD GROUP)

The Dunkard group forms the upper portion of the Coal Measures (formation XIII) of Rogers[68] and is equivalent to the Upper Barren series as recognized by Stevenson.[69] It comprises all the Carboniferous strata above the Waynesburg coal to the youngest not removed by erosion.

The Dunkard group differs from the underlying Monongahela formation in containing more sandstone beds, in a smaller calcareous content, in fewer and less persistent beds of coal, and in a notable increase in the thickness and extent of red shale members. The group comprises two subdivisions, the Greene formation and the underlying Washington formation.

GREENE FORMATION

The Greene formation includes the strata from the top of the Upper Washington limestone to the top of the exposed section. It is composed in major part of soft shales with which are interbedded soft shaly sandstones, thin discontinuous limestone strata, and two to five thin beds of coal. Red shale beds are common and become more abundant and persistent as the formation is traced southwestward into West Virginia and Ohio. Over large areas in Greene County the base of the formation is marked by a fossiliferous carbonaceous shale overlain by a ferruginous shale which was formerly used locally as iron ore. The strata are extremely variable in lithology and thickness, massive sandstones grading into sandy thin-bedded shale within a few hundred feet and limestone grading irregularly into shale. Usually, however, as a given bed thickens it replaces in part those

[68] Rogers, H. D., Second annual report of the geological exploration of the State of Pennsylvania: Harrisburg, 1838.

[69] Stevenson, J. J., Report of progress in the Greene and Washington districts of the bituminous coal fields of western Pennsylvania: Pennsylvania Sec. Geol. Survey Rept. K, pp. 34-56, 1876.

above or below so that the parallelism of the key horizons is only moderately disturbed. The soft shales which constitute most of the formation weather deeply and mantle the slopes with a fine debris which makes it difficult to trace individual beds.

The maximum thickness of the Greene formation in Pennsylvania is attained in Aleppo Township in southwestern Greene County, approximately 750 feet of strata being exposed. Northward and eastward the strata are progressively leveled off by erosion. The interval between recognizable beds varies somewhat irregularly but increases northeastward, at least for the lower portion of the formation. That portion between the base and the Dunkard coal, increases in thickness from an average of 125 feet along the Pennsylvania-West Virginia boundary to nearly 200 feet in the eastern part of the county, an increase of 60 per cent in somewhat less than 30 miles. The higher beds thicken in the same direction, but the rate of thickening can not be estimated accurately within the limited outcrop area. It is worthy of note that the sandstone members are thickest and most persistent in the southern part of the area, whereas the limestone beds become thicker and more continuous toward the north and east as the formation thickens as a whole.

As is shown by the geologic map (Pl. I), the Greene formation crops out only in the southwestern corner of the State, in the western part of Greene County and the southwestern part of Washington County.

Inasmuch as it consists for the most part of fine-grained shales which are very slightly permeable to water and as much of it lies above drainage level, the Greene formation is not a highly productive source of ground water. In most parts of its outcrop area, however, except on the highest hilltops, drilled wells 50 to 125 feet deep obtain yields which are ample for household demands and the watering of livestock. In most wells the water occurs in permeable material along bedding planes, particularly at the top or bottom of beds of dense earthy sandstone a few inches thick, or of limestone. Locally, the sandstone members are coarse-grained and porous, and retain ground water in the inter-granular spaces wherever they lie below drainage level or their structure constitutes a barrier against circulation. The dense beds of sandstone and of limestone which constitute a minor proportion of the formation are also somewhat jointed in the regions of most intense diastrophism, the crevices serving as conduits for the circulation of ground water.

The quality of the water obtained from the Greene formation is shown by analyses of samples from wells Nos. 372, 390, 510, 540, and 550 (Figs. 38, 39 and pp. 77, 79). These waters are only moderately concentrated, ranging from 246 to 436 parts per million of total dissolved solids. Only in the one sample from a source which is below drainage level (No. 550) is sodium (Na) the dominant metallic ion and bicarbonate (HCO_3) the dominant non-metallic ion. This water has a calculated hardness of only 71 parts per million, and is excellent for most uses. It affords a typical example of the natural softening of the ground water, as discussed on pages 85-86.

Those members of the formation which can be recognized from place to place, or are important because of their water-bearing properties are described more fully in the subsequent paragraphs.

WINDY GAP LIMESTONE AND WINDY GAP COAL

In the type region of the Greene formation, in Center Township, Greene County,[69] a thin-bedded limestone crops out 75 to 110 feet below many of the highest hilltops. This is known as the Windy Gap limestone from the locality of that name near Morford, Aleppo Township.

Beneath this limestone is a thin bed of impure coal or carbonaceous shale.

The beds of this horizon are not known to be a source of ground water inasmuch as they occur far above drainage level in small scattered caps on the highest hills of the region of outcrop.

GILMORE SANDSTONE

The Windy Gap coal is underlain by reddish shale. The Gilmore sandstone lies 50 to 85 feet below the top of the Windy Gap limestone. It has a maximum thickness of 50 feet, and crops out on most of the higher hills in Gilmore, Springhill, Aleppo, and Jackson townships, southwestern Greene County. Farther to the south, north, and east it has been removed by erosion. This sandstone is a corse-grained massive rock which usually underlies a well-marked bench on the hillsides and in numerous places weathers into cavernous cliffs and large residual angular boulders.

The lower portion of the Gilmore sandstone, or the interlaminated thin beds of shale and sandstone which lie immediately beneath, supplies numerous farmstead wells on the flanks of the Nineveh syncline (Pl. I) in Morris, Jackson, and other townships of central Greene County. Nos. 513 (Fig. 38 and p. 322) and 539 (p. 318) are examples. Inasmuch as the member is cut through by many streams, the rate of inflow to the well seldom exceeds one gallon per minute, and the water is confined under low hydrostatic head. Hence it is necessary to drill 25 to 50 feet below the water-bearing bed in order to provide adequate storage volume within the well.

NINEVEH SANDSTONE AND ASSOCIATED BEDS

The Gilmore sandstone is underlain by 135 to 200 feet of soft reddish shale, with which many thin-bedded irregular sandstone lentils and one to three discontinuous limestone strata are interbedded. The uppermost of the limestone beds lies close below the Gilmore sandstone and attains a maximum thickness of 10 feet. Part or all of the lower 50 feet of this group of shale and sandstone beds is occupied by a massive or laminated reddish sandstone known as the Nineveh sandstone.

The horizon of the Nineveh sandstone is reached by wells 50 to 100 feet deep along the flanks of the Nineveh and Waynesburg synclines (Pl. I) in western Greene County. Wells 540 of Jackson Township (Fig. 38 and p. 318) and 554 of Wayne Township (p. 326) are representative. The member yields water at rates as large as 5 gallons per minute. Even in the axial portion of the Nineveh syncline, however, in western Center Township, it is trenched by the deeper streams. In the valley of Grays Fork, for instance, the member crops in the hillsides about 75 feet above the stream bed at the syncline axis $2\frac{1}{2}$ miles east of Graysville. Hence ground water is erratic in occurrence

[69] Stevenson, J. J., op. cit., p. 35.

and is not confined under any great hydrostatic head. So far as is known, no water wells have been drilled to this sandstone along the syncline axis although it should be a moderately certain source in Aleppo, Jackson, eastern Richhill, and western Center townships. In this district, the top of the member is 250 to 350 feet below the highest hilltops.

As shown by the analysis of a sample from well 540 (p. 79) the water from the Nineveh sandstone is of fair quality for domestic uses although it is hard and is sufficiently concentrated in dissolved iron to be slightly troublesome in laundering.

NINEVEH COAL, NINEVEH LIMESTONE, AND ASSOCIATED BEDS

The Nineveh coal, which lies immediately below the Nineveh sandstone and its associated beds of limestone and shale, is one of the important horizon markers of the Greene formation.

Below it is 10 to 12 feet of carbonaceous shale and the Nineveh limestone, which is 2½ to 10 feet thick.

The Nineveh limestone is underlain by 85 to 100 feet of reddish and dark-colored shales interbedded with discontinuous thinly laminated gray and reddish sandstone, of which the thickest attains a maximum of 15 feet.

These shale and sandstone beds yield small supplies of ground water from bedding planes and from crevices of the sandstone layers in the Nineveh and Waynesburg synclines (Pl. I) of Greene County. Typical wells are No. 514 of Morris Township (Fig. 38 and p. 322) and No. 515 of Washington Township (p. 324). Well 515 is of special interest in that it illustrates the occurrence of a body of ground water, small to be sure, retained in the axis of a syncline nearly 300 feet above Tenmile Creek some 3 miles to the south.

FISH CREEK SANDSTONE

The first stratigraphic division below the Nineveh limestone that can be traced for a considerable distance is the Fish Creek sandstone whose top is 200 to 300 feet above the base of the Greene formation. At the type locality along Fish Creek in Springhill Township, Greene County, this sandstone is massive, locally coarse-grained, and light grayish to brownish on fresh fracture; it is also a bluff-maker. Its maximum thickness in this district is 100 feet. A massive rather continuous bed 10 to 40 feet thick forms the lower part of the member and is a prominent bluff-maker along the forks of Tenmile Creek in the region about Graysville and Nineveh. Northeastward, in Washington County, the member grades irregularly into thin-bedded and shaly sandstone which is locally reddish in color and encloses as many as three discontinuous thin limestone beds.

The Fish Creek sandstone is widespread in the Nineveh syncline (Pl. I), and extends northward beyond Greene County to the latitude of Washington. It is approximately at stream level where the syncline axis is cut by Fish Creek in the extreme southwestern corner of the State and by Grays Fork in Center Township. In Morris Township of Washington County, however, it is about 175 feet above stream level where the axis crosses Tenmile Creek. The member is also extensive in the Waynesburg syncline to the east, but is cut through by

all drainage ways and in the region north of Waynesburg is found only near the tops of the highest ridges.

The type phase of the Fish Creek sandstone, which is known to the drillers as the Bluff sand in northwestern Greene County and contiguous parts of Washington County, promises ample and permanent farmstead supplies wherever it is entered at a distance from the outcrop, and yields at the rate of several gallons per minute whenever it is found below the level of surface drainage. Typical wells in Greene County are No. 518 of Center Township (Fig. 38 and p. 312) and No. 551 of New Freeport Borough (p. 322). In well No. 1094, Gilmore Township (p. 316), 144 feet of 13-inch casing was set to exclude ground water while drilling was continued. This casing extends slightly below the base of the Fish Creek sandstone, a fact which suggests that member to be a water bearer at that locality. Northward from Center Township the member becomes progressively more shaly and less permeable. In extreme cases the member yields only a few gallons of water per hour to wells. The water-yielding capacity of the shaly facies of the Fish Creek sandstone in Washington County is represented by No. 382 of East Finley Township (p. 344) and No. 383 of South Franklin Township (p. 354). Nowhere is water retained under considerable hydrostatic head, inasmuch as the surface drainage cuts nearly if not quite through the member at the axes of the synclines.

The water from the Fish Creek sandstone is probably not greatly different in quality from that of the overlying Nineveh sandstone. (See No. 540, p. 79).

CLAYSVILLE LIMESTONE

In the southwestern part of Washington County the horizon of the Fish Creek sandstone is occupied by shale and shaly sandstone which enclose the Claysville limestone. This limestone, whose top is 205 to 225 feet above the base of the Greene formation and 100 to 120 feet below the Nineveh coal, occupies a stratigraphic horizon which is somewhat above that of the base of the typical Fish Creek sandstone of Greene County. The Claysville limestone is the most prominent member of the Greene formation in southwestern Washington County.

The Claysville limestone is not known to be a ground water reservoir, although it is likely that there is some circulation along joints and bedding plane channels of small size, especially in the vicinity of outcrops along the upturned flanks of the synclines.

DUNKARD COAL

The Dunkard coal, which lies below the Fish Creek sandstone or its shaly equivalent, is one of the most reliable horizon markers for the Greene formation. It lies approximately 200 feet below the Nineveh coal and from 100 to 200 feet above the base of the Greene formation. This interval is from 100 to 125 feet along the western boundary of Greene County and increases eastward with essential regularity to a maximum of 170 to 200 feet in the northeastern part of the county. In the type region in Center Township the coal is 12 to 21 inches thick, including a thin parting of clay near the center.

PROSPERITY LIMESTONE

Beneath the Dunkard coal and separated from it by 10 to 35 feet of reddish sandy shale and sandstone lies the Prosperity limestone. The type locality is at the village of Prosperity, Morris Township, Washington County. This limestone resembles strongly the Upper Washington limestone member, which occurs 100 to 180 feet below it, and may be mistaken for that bed. The Prosperity limestone is persistent over the southern half of Washington County and its thickness ranges between 10 and 20 feet.

The Prosperity limestone is usually underlain by a group of interbedded shales and sandstones about 50 feet thick which yield limited supplies of ground water in central and southern Greene County. The source lies in bedding plane conduits, especially at the upper surfaces of the dense and very slightly permeable sandstone lentils. Typical wells are No. 522, Center Township (Fig. 38 and p. 312); No. 531, Franklin Township (p. 316), and No. 558, Wayne Township (p. 326). While drilling gas wells at sites No. 1093 of Gilmore Township (p. 316) and No. 1096 of Wayne Township (p. 326), it was found necessary to set casing through these beds in order to exclude water. Such conditions are not general, however, and the location and volume of bodies of ground water seem to be extremely erratic. The beds are not known to be water-bearing at any points north of Center and Franklin townships.

TENMILE COAL

The first distinctive bed below the Prosperity limestone is the Tenmile coal. It attains a maximum thickness of 3 feet and is the most valuable coal bed of the Greene formation.

DONLEY LIMESTONE AND ASSOCIATED BEDS

The Tenmile coal is underlain by 15 to 30 feet of laminated gray sandstone which is locally massive and, less commonly, shaly. Since the top of this sandstone is usually less than 50 feet above the base of the Greene formation, the trace of its outcrop is approximately that of the boundary of the formation (Pl. I). Hence the member is continuous beneath cover in the Nineveh syncline and has been exposed only by the principal drainage ways in the Waynesburg syncline.

This sandstone is known to be water-bearing at widely separated localities in the southwestern part of the district, and is a potential source of small supplies throughout its outcrop area. Its water-yielding capacity in Washington County is represented by spring 380 of East Finley Township (Fig. 39 and p. 344), and by well 390 of Amwell Township (p. 334). For Greene County, wells 511 of Richhill Township (p. 324) and 550 of Springhill Township (p. 324) are representative. The water is confined under moderate hydrostatic pressure, and, along the synclinal axes, rises as much as 75 feet above the water-bearing bed. When the member is penetrated high on the flanks of the fold, however, the head may be less than 10 feet so that it is necessary to drill deeper to provide adequate storage volume within the well.

The chemical character of the water from these beds is represented by analyses of samples from wells 390 and 550. The first of these waters is moderately concentrated and of fair quality for household

and other uses, although it is rather hard. Well 550, however, reaches the water-bearing sandstone below drainage level and its water has a hardness of only 71 parts per million. This water is of very good quality for most purposes.

The sandstone described in the preceding paragraph rests upon the Donley limestone, which in its typical development in western Washington County is 5 to 6 feet thick.

The Donley limestone or its shaly equivalent is water-bearing in a relatively small area in central and southwestern Washington County and in adjacent parts of Greene County. Small but permanent supplies are won from bedding plane passages, seemingly at localities on the flanks of the synclines and usually but a fraction of a mile down the dip from the outcrop of the member. Conditions in Washington County are typified by wells 372 of South Strabane Township (Fig. 39 and p. 354) and 381 of East Finley Township (p. 344). Well 510, Richhill Township (p. 324) is representative for Greene County. The passages through which ground water circulates are small solution channels formed after the member had been consolidated and exposed to weathering and erosion. Hence, they depend upon the position of the bed with reference to the present erosion surface and are extremely erratic in location and continuity so that the water-bearing properties of the member vary widely from place to place.

Analyses 372 and 510 (pp. 77, 79) represent the chemical nature of the water from the shaly facies of this member. These waters are moderately concentrated and of fair quality for domestic uses, although hard. The predominant constituents are calcium (Ca) and bicarbonate (HCO_3).

UPPER WASHINGTON COAL

The interval below the Donley limestone to the base of the Greene formation is occupied by variable beds of laminated or massive sandstone and shale which enclose one discontinuous thin coal bed, the Upper Washington coal.

WASHINGTON FORMATION

The Washington formation underlies the Greene and includes all beds from the top of the Upper Washington limestone to the top of the Waynesburg coal. The bottom of the formation thus defined is at the base of the Cassville shale or, where that shale is absent, the base of the Waynesburg sandstone. The Washington formation, like the overlying Greene formation, comprises variable beds of shale and sandstone, thin-bedded and discontinuous limestone, and several beds of coal of local economic value. Individual beds differ greatly in lithology from place to place, one type of sediment grading into another, sometimes rather abruptly. They also vary in thickness, the variation being in part due to local discordance in deposition. The Washington formation also resembles the Greene in that its limestone members become thicker and more persistent toward the north and east and its sandstone members in general are thickest in the southern part of the outcrop area. It differs from the Greene, however, in that it is much

more evenly bedded, much more calcareous, and contains more continuous and thicker beds of coal.

Like all other formations of the Carboniferous system, the Washington formation thickens notably eastward or southeastward within its relatively small outcrop area in Washington and Greene counties. Along the western margin of the area it is 275 to 300 feet thick, and it attains a miximum thickness of approximately 440 feet along the Youghiogheny Valley to the east. Hence the formation thickens about 45 per cent in a distance of 30 miles. The average thickness of the formation is 330 feet.

The Washington formation crops out in many widely separated portions of the area south of Pittsburgh and west of the Dulany and Chestnut Ridge anticlines (Pl. I).

With the exception of its basal member, the Washington formation is not a prominent source of ground water, although drilled wells between 35 and 100 feet deep are usually successful in obtaining water supply to meet the needs of household and of live stock. A minor proportion of the successful wells are deeper, reaching a maximum of 250 feet, and a very few have been unsuccessful. The soft shales, which constitute the major portion of the section, are very poor water-bearers although a limited circulation does occur along bedding planes. Those parts of the formation which comprise interlaminated beds of shale and sandstone each a few inches to several feet thick, the so-called "slate and shells" of the well driller, are usually productive, especially where they are below drainage level or where the structure impedes circulation. In these members, the source lies in bedding planes. The limestone members, of which several are rather widespread, carry water in small bedding plane and joint channels along the flanks of the synclines, especially below drainage level. The available data seems to indicate, however, that circulation is not active far from the outcrop of the beds or where they pass much more than 50 feet below drainage level. Being composed of thin layers of limestone separated by shale, these members would yield readily to diastrophic forces and were not extensively fractured during the deformation of the Carboniferous sediments. Furthermore, the post-Permian history of southwestern Pennsylvania has been repeated uplift and progressive erosion, so that the beds have been worn away about as rapidly as solution passages have developed. Hence these limestone members are not usually permeable to ground water beneath deep cover. The sandstone members of the Washington formation are for the most part argillaceous rocks which are not highly permeable to water and yield supplies of small magnitude. Locally, however, their coarser facies are moderately productive, especially where they lie below drainage level.

The basal member of the Washington formation in a large part of the area is the Waynesburg sandstone, the outstanding water-bearing member of the entire Permian series. As is brought out in subsequent paragraphs, this sandstone supplies wells of large yield over a relatively extensive area.

The water of the Washington formation is for the most part moderately concentrated in dissolved mineral matter, and of good quality for any domestic or industrial use. At a few places, however, the water from the Waynesburg sandstone is highly mineralized and is of

inferior quality. Although the calcium (Ca) and bicarbonate (HCO_3) radicles are the most abundant constituents, the waters are not objectionably hard except those from the limestone members.

UPPER WASHINGTON LIMESTONE

The Upper Washington limestone, the top member of the Washington formation, is the most persistent and uniform bed of the entire Permian series, a characteristic which led to its selection as an index for subdividing the rocks of that series. Due to the variable thickness of the intervening strata, the top of this bed is between 560 and 750 feet above the Pittsburgh coal, the average interval being 650 feet. In the type region near the city of Washington, the bed attains a maximum thickness of 30 feet. Over much of Greene County the Upper Washington limestone is not more than 5 or 10 feet thick. The general features of the upper part of this limestone bed in the type region are well shown by Figure 24.

Figure 24.—Interbedded shale and limestone of Upper Washington limestone as exposed in abandoned road metal quarry on Waynesburg Pike, 2.3 miles south of Laboratory, Washington County.

The Upper Washington limestone is very extensive in Greene and Washington counties, as shown by the geologic map (Pl. I) on which it is represented by the boundary between the Greene and Washington formations.

The Upper Washington limestone is not a conspicuous water bearer, although its outcrop is marked by many small springs, and at many places it yields farmstead supplies to drilled wells 50 to 100 feet deep. In general, the springs along the outcrop are fed by vadose or soil water which percolates downward through the weathered shales above

the limestone and then seeps laterally along the top of the impermeable undecayed limestone to a favorable point of discharge. Hence, the springs do not indicate the water-bearing properties of the limestone beneath cover. Wells drilled to the Upper Washington limestone obtain their yields at its upper surface, in enlarged joint crevices of the limestone layers, or in the inter-laminated layers of soft calcareous shale. The latter type of passage is largely the result of the solvent action of circulating ground water and is best developed where the bed lies on the flank of a syncline and comparatively close to the outcrop. The water in the Upper Washington limestone is not confined under great hydrostatic head and usually does not rise in the well much more than 25 feet above the point at which it is encountered. The water-bearing properties of the member in Washington County are represented by well 379 of East Finley Township (Fig. 39 and p. 344). For Greene C unty, conditions are typified by wells 512 of Graysville Borough (p. 316), 543 of Whitely Township (p. 328), 552 of Gilmore Township (p. 316), and 1101 of Perry Township (p. 322). Of the many springs along the outcrop, No. 388 of Amwell Township, Washington County (p. 334), is characteristic. The Upper Washington limestone is not usually permeable where it lies more than 50 feet below the level of nearby surface drainage ways. Of those wells which reach the Upper Washington limestone beneath 75 feet or more of cover, some obtain a small yield at the top of the member or in joint crevices, especially along synclinal axes, but most no not obtain adequate supplies. This condition is typified by Nos. 558 and 561 of Wayne Township, Greene County.

JOLLYTOWN LIMESTONE, JOLLYTOWN COAL, AND ASSOCIATED BEDS

The Upper Washington limestone is underlain by soft reddish and yellowish sandy shales and thin-bedded sandstones which here and there grade laterally into massive coarse-grained beds. The general character of these interlaminated beds is well shown by the accompanying photograph (Fig. 25). Over large areas these rocks enclose the Jollytown limestone and the Jollytown coal, beds which serve as valuable key rocks in determining the base of the Greene formation. The Jollytown limestone lies 20 to 40 feet below the Upper Washington limestone, and is usually about 5 feet thick.

The Jollytown limestone is not of value as a water-bearer although its outcrop may be a locus for many small springs. Inasmuch as it is limited in areal extent and lies close below the Upper Washington limestone, to which it is inferior as a source of water, it is usually overlooked by the driller.

The Jollytown limestone is underlain successively by 20 to 30 feet of variable sandstones and shales, by the Jollytown coal, and by about 35 feet of sandy shale and flaggy to thick-bedded sandstone. The Jollytown coal is a discontinuous bed which at some places is separated into an upper and lower band by as much as 15 feet of yellowish shale. It is not more than 20 inches thick and is accompanied by nodular iron carbonate in the overlying shale.

The variable shales and sandstone which overlie the coal yield many small springs and well supplies along the flanks of folds in central Greene and south central Washington counties. Spring 384 in Morris

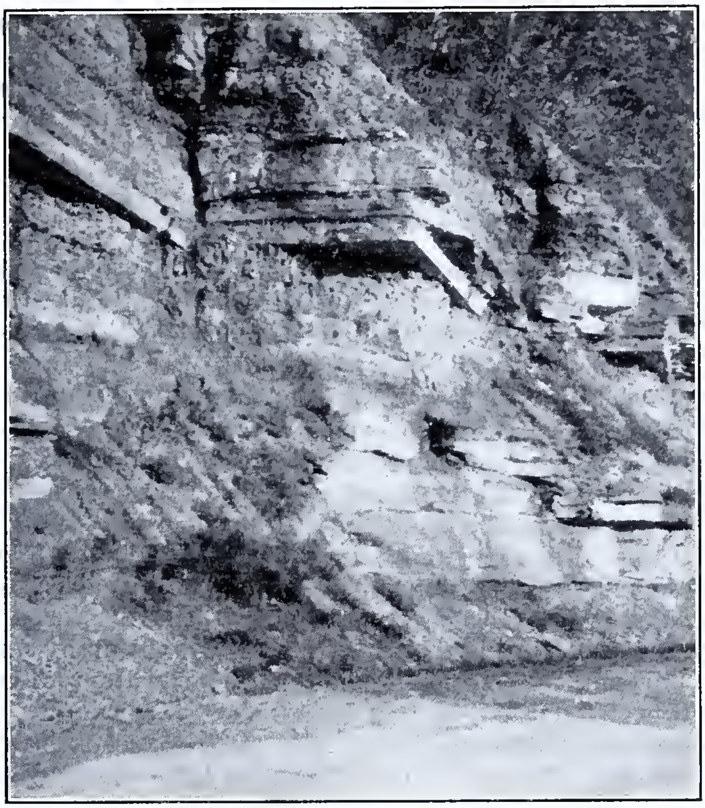


Figure 25.—Interbedded shale and sandstone below Upper Washington limestone, as exposed along east bank of Tenmile Creek half a mile east of Rogersville, Greene County.

Township* and wells 386 and 391 in Amwell Township are typical of conditions in Washington County. Representative wells in Greene County are No. 520, Center Township, No. 557, Wayne Township; and No. 562, Perry Township. Most wells in these shales and sandstones do not yield more than one gallon per minute, and the water is not confined under large hydrostatic head. It is not likely that these beds would be water-bearing beneath deep cover, except in the massive pebbly phase which replaces the Jollytown limestone in the vicinity of Claysville.

The sandstone which underlies the horizon of the Jollytown coal is persistent in the Waynesburg syncline (Pl. I) in Center and Wayne townships of Greene County and where it lies below drainage level, yields 5 to 20 gallons per minute to drilled wells. Representative wells are Nos. 519, 523, 524, and 1,078 of Center Township and Nos. 555 and 556 of Wayne Township. The permeability is indicated by well 524 whose reported yield is equivalent to a specific capacity of nearly one gallon per minute for each foot of drawdown. Water is retained under moderate hydrostatic pressure. Nothing is known of the water-bearing properties of this member in the Nineveh syncline to the west, although if its lithologic characters are the same it should

* From here on it will be assumed that the reader is familiar with the well maps and will refer to the tables in the county descriptions for data concerning wells and springs referred to by number.

be a source of ground water. Along the axis of the syncline, in western Center and Springhill townships, the member would be expected between 200 and 300 feet below the beds of the major creeks. At strategic locations on either flank of the fold, the member would be found even closer to the surface. It is not likely that the hydrostatic pressure is sufficient to cause wells to flow.

MIDDLE WASHINGTON LIMESTONE

The top of the Middle Washington limestone lies immediately below the sandstone which has just been described and, on the average, 105 feet below the top of the Upper Washington limestone, although this interval ranges between 85 and 135 feet. In the type region the member is from 10 to 30 feet thick and is made up of four or more layers separated by shale.

The Middle Washington limestone carries small bodies of ground water in the vicinity of its outcrops in southern Washington and northern Greene counties. As in the case of the overlying Upper Washington limestone, circulation takes place along small solution passages which follow bedding planes and joint cracks, so that the water-bearing properties vary greatly from place to place. Moreover, the Middle Washington limestone is wanting in many large areas, so that its horizon is a most erratic source of water. The majority of household wells drilled to this member in the vicinity of its outcrop are successful, although few of the yields exceed the rate of one gallon per minute. No wells are known to have encountered ground water at this horizon beneath deep cover, however. Inasmuch as the Middle Washington limestone is usually ferruginous, the ground water obtained from it is likely to be of inferior quality, on account of a large content of dissolved iron. Typical wells and springs of this member in Washington County are No. 365 of Claysville Borough and Nos. 385 and 392 of Amwell Township and No. 394 of West Bethlehem Township. Well 525 of Franklin Township is representative for northern Greene County.

LOWER WASHINGTON LIMESTONE AND ASSOCIATED ROCKS

The Middle Washington limestone is underlain successively by 5 to 25 feet of yellow to brownish shale and by 35 to 60 feet of black carbonaceous or cannel-like fossiliferous shale. The brown shale is locally replaced in whole or in part, by reddish, thin-bedded to massive sandstone.

The sandy facies of this group of beds seems to be thickest and most persistent in a zone of irregular width which trends southward through the Borough of Washington into Center and Wayne townships of central Greene County, crossing the axes of the Nineveh and Waynesburg synclines (Pl. I) at an acute angle. Adequate data are not at hand, however, to trace the boundaries of this zone with any precision. Southward from Washington this sandstone lies for the most part below the level of surface drainage, so that ground water is retained under moderate hydrostatic pressure. Yields ranging from 1½ to 15 gallons per minute are reported. Inasmuch as the member does not retain its sandy permeable texture along much of the zone of outcrop to the east and west, however, recharge is somewhat hampered.

Hence, the member is not as promising a source of ground water as it would be otherwise. Well 371 in Washington Borough is typical of developments in central Washington County. Of conditions farther to the south, in Greene County, wells 521 and 1,078 of Center Township and 559 of Wayne Township are representative. It is reported, however, that well 558, although but half a mile northeast of well 559, passed entirely through these beds without finding water. Whether or not the sandy facies was found is not known. Northward from Washington, the sandy facies of the member persists and yields many supplies of household magnitude. In this district, however, it is cut through by many of the streams so that it has been drained in many places.

The shaly facies of the beds which lie beneath the Middle Washington limestone is well developed in the eastern and western third of both Washington and Greene counties, although many thin sandstone lentils occur locally. This facies yields between 2 and 10 gallons per minute to drilled wells, the largest yields being found along syncline flanks and below the plane of surface drainage. The permeability of the beds beneath deep cover is not known. The water obtained from the shales of this group is moderately hard in most instances. Typical developments in Washington County are the wells of group 366, in Claysville Borough and the shallowest of the Claysville municipal wells, No. 367, which is located in Donegal Township. Others in Greene County are No. 526 of Waynesburg Borough and Nos. 541, 542, and 1,088 of Whiteley Township.

Beneath the carbonaceous shale, to which reference has been made above, lies the Lower Washington limestone, whose top is 150 to 220 feet below the top of the Washington formation. The Lower Washington limestone attains a maximum thickness of 30 feet in Washington County, but it is thin or absent over the greater part of Greene County. In the type region it comprises top and bottom layers, each 2 to 3 feet thick.

The Lower Washington limestone yields water supplies of household magnitude in the vicinity of its zone of outcrop in Washington and northern Greene counties, although, as is characteristic of the other limestone members of Permian age, its water-bearing properties are erratic in detail. Moreover, this limestone is extremely discontinuous and hence is not of great consequence as a source of ground water. Typical developments are well 343 of Cross Creek Township of northern Washington County, and well 536 of Jefferson Township, northeastern Greene County. The water obtained from the member is usually moderately hard.

WASHINGTON COAL

The Washington coal lies close beneath the Lower Washington limestone. It varies from 6 inches to 11 feet thick in Washington County, although where it is thick many clay partings are present and the bed is not usually of economic value. The Washington coal is the most persistent coal bed of the Dunkard group and is an excellent horizon marker.

The coal beds of the Carboniferous rocks are quite impermeable, so that limited bodies of ground water may be trapped above them at localities of favorable structure. Such is likely to be true of the Wash-

ington coal, although no instances of ground water being found in association with that member are known.

WASHINGTON SANDSTONE AND LITTLE WASHINGTON COAL

The Washington coal is underlain locally by a few inches of fireclay and then by 6 to 28 feet of reddish shale which passes by lateral gradation, either in whole or in part, into the Washington sandstone. In the type region about Washington this sandstone is massive, although elsewhere it is thinly laminated or shaly.

The type phase of the Washington sandstone is presumably a source of moderate ground water supplies over much of its relatively limited outcrop area southward and westward from Washington, although it is so inferior to the underlying Waynesburg sandstone in water-yielding capacity that it is not extensively developed. Locally in Greene and Washington counties it is known to the well driller as the Bluff sand, from confusion with the Waynesburg sandstone member below. The 140-foot well of the Claysville municipal group, No. 367, which is located in Donegal Township, reaches the horizon of this member, although the lithology and water-yielding capacity of the stratum are not known. The shaly facies of the Washington sandstone supply relatively shallow wells in the Waynesburg syncline of southeastern Washington County. Well 395 of West Bethlehem township is representative. Wherever the member is below drainage level the yields obtained are moderate but permanent and of the order of 5 or 10 gallons per minute. Water is stored under moderate hydrostatic head. In general, however, the horizon of the Washington sandstone is not a prominent source of ground water.

WAYNESBURG "B" COAL AND ASSOCIATED ROCKS

Beneath the Little Washington coal is a group of shale and sandstone strata which enclose locally two thin limestone beds and one seam of coal. This group has a thickness of 40 to 80 feet and extends to the Waynesburg "A" coal.

The Colvin Run limestone is one to 10 feet thick and carries ground water in the erratic manner typical of the thin-bedded Permian limestones, on the flanks of the folds and for a relatively short distance from the outcrop in the direction of dip. In these outcrop belts small bodies of water are held under very low hydrostatic head. Yields are usually ample for household demands, although the water is rather hard by virtue of its comparatively large content of calcium and magnesium. Wells 401 of East Pike Run Township and 404 of Centerville Borough typify conditions in extreme southeastern Washington County; well 528 of Waynesburg Borough is representative for eastern Greene County. Nothing is known of the value of this horizon as a source of ground water in the northern and western portions of Washington County or at any locality in the vicinity of the Pennsylvania State boundary line.

The thin fine-grained calcareous shale which underlies the Colvin Run limestone is not usually a water-bearer, although in one instance, well 481 of South Huntingdon Township, Westmoreland County, this member yields a moderate amount of hard water. This locality, however, is far down on the western flank of the Fayette anticline and close

to the outcrop of the member. The occurrence is presumably local and erratic, rather than a general index of the water-yielding capacity of the shale in the region to the west.

WAYNESBURG "A" COAL AND MOUNT MORRIS LIMESTONE

The Waynesburg "A" coal, also known as the Zollarsville coal, lies just beneath the thin shale that underlies the Colvin Run limestone. It is not of consequence, as a source of ground water, although it does carry small bodies of water locally in the vicinity of the outcrop. Well 345 of Cross Creek Township, western Washington County is typical. This well, located on the east flank of the West Middletown syncline (Pl. I) is barely adequate for household use, the rate of inflow being probably but a small fraction of one gallon per minute. The water is not confined under hydrostatic pressure. Furthermore, it is of inferior quality by virtue of the large content of ferrous sulphate which originates with the oxidation of the pyrite of the coal. Well 1,081 of Franklin Township, central Greene County, found water at the top of this member at a depth of 330 feet below the surface on the western flank of the Bellevernon anticline although nothing is known of the yield or the quality of the water. No other instance has been reported in which the Waynesburg "A" coal is accompanied by ground water beneath thick cover. In general this horizon is neither a productive nor a consistent source of water.

WAYNESBURG SANDSTONE

The type locality of the Waynesburg sandstone is near the place of that name in central Greene County. In that region the stratum is about 70 feet thick and is divided into two nearly equal portions by a bed of sandy shale. Each portion is light gray or buff in color, micaceous, and usually arkosic or feldspathic. The upper division is typically cross-bedded and flaggy, although the lower division is generally massive and friable and locally coarse-grained or even pebbly. The lower division is a bluff maker and in many places its outcrops are somewhat cavernous. South of the type locality the rock becomes more and more pebbly and a persistent conglomeratic facies is recognized over wide areas in West Virginia. Toward the east and north, also less notably toward the west, the sandstone thins, loses its massive character, and passes into a laminated sandy shale. It is poorly developed or missing in northern and central Washington County as far south as the city of Washington, it is shaly and thin at many places in western Greene County, and becomes a sandy shale along the Monongahela River and in the Uniontown syncline (Pl. I) to the east. It is recurrent as a thick coarse-grained stratum in the Latrobe syncline of Westmoreland County, forming disconnected small erosion remnants on some of the high hills east of Klondike and north of Mount Pleasant. The sinuous trace of the outcrop of the Waynesburg sandstone within these areas is depicted on the geologic map (Pl. I) by the boundary which separates the Washington formation from the underlying Monongahela beds.

The Waynesburg sandstone, especially the massive and coarser-grained lower portion, is by far the outstanding water-bearing member of the entire Permian series and has been extensively developed in that portion of Washington and Greene counties which lies east of the

meridian of 80° 15′ west longitude, under the driller's local name of the Bluff sand. The details of local stratigraphy are too imperfectly known, however, to permit certain correlation of the water-bearing stratum in some cases. The water-yielding capacity of the sandstone is represented in the tabulated data for Washington County by well 348 of Cecil Township, 351 and 352 of Peters Township, 373 of Somerset Township, 396 of West Bethlehem Township, and 403 of Beallsville Borough. For Greene County, well 516 of Morgan Township, 527 and 528 of Waynesburg Borough, 530 of Franklin Township, 533 of Jefferson Township, 560 adjacent to Wayne Township, and 563 of Mount Morris Borough, are representative. In a large part of Washington County the sandstone is above drainage level and is only moderately permeable, so that although it is a rather persistent water-bearer the yields are rather small, few exceeding 5 gallons per minute. Farther south in Greene County, the coarser facies of the member are more permeable and yields as large as 65 gallons per minute are obtainable where the member lies below drainage level. The specific yield of individual wells is not known precisely but is of the magnitude of 2 gallons per minute for each foot of drawdown in wells at Waynesburg. Water is confined within the member under moderate hydrostatic pressure, and at Waynesburg rises about 30 feet above the level of the creek bed although 10 to 18 feet below the surface of the ground at the various well sites. It is noteworthy that wells reported to have been drilled to a depth of 200 feet at the flour mill and at the electric light plant at Waynesburg failed to obtain water, although borings of that depth should have penetrated the Waynesburg sandstone. These wells are not more than half a mile from No. 527, to which reference has been made above. This reported phenomenon is directly opposed to the mass of experience with the Waynesburg sandstone elsewhere, and, if authentic, points to abrupt changes in permeability of the member from place to place. It should be noted further that gas wells 1050 of Cross Creek Township and 1055 of Nottingham Township, both in northern Washington County, encountered fresh water at the horizon of the Waynesburg sandstone, but the lithologic nature of the bed and the yields therefrom are not known. The deepest of the three wells of the Claysville municipal group, No. 367, Donegal Township of western Washington County, also bottoms at this horizon, but again the lithology and water-yielding capacity of the bed are not known. This site lies to the west of the area known to be underlain by the typical phase of the Waynesburg sandstone and on the flank of the Claysville anticline.

In central Greene County there are two wells which flow or have flowed by artesian pressure and are probably supplied by the Waynesburg sandstone, although strict correlation of the water-bearing stratum is not possible. These are No. 1078 of Center Township and No. 532 of Franklin Township. The first of these two wells, No. 1078, is reported to have found water in sandstone, probably the Waynesburg sandstone, at a depth of 200 feet below the surface and to have flowed by artesian pressure before the member was cased off. This well is in the valley of South Fork of Tenmile Creek and at the southern terminus of the axis of the Amity anticline, a structure which plunges notably southward. The magnitude of the artesian head at the surface of the ground is not known but is presumably not more than a few tens of feet. Well 532 (Fig. 14, p. 66), is in the bed of Smith

Creek on the western flank of the southward-plunging Bellevernon anticline about 3 miles south of Waynesburg. The flow during October, 1926, was not less than 25 gallons per minute with considerable leakage outside of the casing. Furthermore, it was reported that the yield had not declined noticeably during the 12-year life of the well. It is probable that the water would not rise by artesian pressure more than 10 feet above the surface of the ground. The static level of ground water in the Waynesburg sandstone being about 30 feet above the level of the creek bed at Waynesburg, the area of artesian flow is probably limited to the stream beds of South Fork between Waynesburg and Rogersville and of Smith Creek for not more than 4 miles southward from Waynesburg. Possibly also the bed of Ruff Creek to the north would yield flowing wells in the vicinity of the axis of the Waynesburg syncline.

It is seemingly anomalous that the only flowing wells of this district should occur in the axial portions of anticlinal folds, in direct opposition to the accepted hydraulics of the artesian condition. It is significant, however, that the anticlinal axes which yield flowing wells rise northward with relative steepness and bring the coarse-grained permeable phase of the Waynesburg sandstone to the surface to create a zone of recharge. Under these conditions the axial portions of the folds act as artesian slopes. To a large extent also the anomaly is fortuitous in that borings of sufficient depth to reach the water-bearing stratum have not been made in the deepest part of the Waynesburg syncline, which passes midway between the two sites of flowing wells.

The records of gas wells drilled in the region of the Nineveh syncline of western Greene County do not report the occurrence of water at the horizon of the Waynesburg sandstone, although this absence of record does not necessarily indicate that the member is not water-bearing. Along the axis of the syncline, the sandstone would be 500 feet or more below the plane of surface drainage and well below the zone of active ground water circulation, so that any water held therein is likely to be highly saline. This is substantiated by Stevenson's[69] note that a well drilled in the vicinity of Rogersville found the Waynesburg sandstone to be saliferous.

The chemical character of the water in the Waynesburg sandstone below drainage level in Washington and Greene counties, is typified by the analyses of samples from wells Nos. 527, 532, and 560 (Fig. 38 and p. 79). These waters are moderately to highly concentrated, the total dissolved solids ranging from 244 to 1,654 parts per million. The noteworthy ionic constituents are the sodium (Na), calcium (Ca), chloride (Cl), and bicarbonate (HCO_3) radicles. These waters are not excessively hard but the high content of sodium, chloride, and bicarbonate radicles is objectionable. No. 527, especially, is of decidedly poor quality and is not suitable for domestic use or for most industrial purposes other than cooling. It will be noted from these three analyses that the total dissolved solids decrease progressively toward the south as the sandstone passes ever deeper beneath cover. This change takes place largely by decrease of sodium (Na) and chloride (Cl) radicles and to a lesser extent of bicarbonate, although these losses are accompanied by relatively slight gains in calcium (Ca) and in the sulphate (SO_4) radicles. A sample from well No. 533 indicates

[69] Stevenson, J. J., op. cit., p. 58.

the quality of the water obtained above drainage level, there being a notable relative abundance of the sulphate (SO_4) radicle, presumably from the oxidation of the mineral pyrite. The significance of these constituents with respect to the utilization of the water has been discussed in the section on quality of the ground water.

In western Fayette County, in the Lambert syncline, a sandstone member which occupies the approximate stratigraphic position of the Waynesburg sandstone of the type region supplies some drilled wells, of which No. 597 of Redstone Township is typical. In this syncline the member lies far above drainage level and the yields obtained are small, usually about one gallon per minute. Somewhat farther west, the Waynesburg sandstone carries local bodies of ground water on the flanks of the Brownsville anticline as represented by well 596 of Luzerne Township. Inasmuch as the member is relatively impermeable over much of the area as well as discontinuous, it is not a prominent source of ground water in Fayette County. To the north, in Westmoreland County, the member is recurrent in its coarse-grained permeable phase, but, being found only on the summits of the highest hills of the Latrobe syncline, is not a source of water.

CASSVILLE SHALE

In Greene County the Waynesburg sandstone is underlain locally by a bed of limestone 1 foot thick and in turn by dark-colored or reddish sandy shale which ranges from a thin film to a bed 12 feet thick.

Being discontinuous in the extreme, the Cassville shale is not a consistent source of ground water over the whole region. Locally, however, it yields moderate supplies, especially on the flanks of synclines and in the vicinity of the outcrop. Typical wells are No. 376 of Fallowfield Township, Washington County; No. 486 of South Huntingdon Township, Westmoreland County; and No. 544 of Whiteley Township, Greene County. Even where it is above drainage level, this shale yields as much as 10 gallons per minute to wells which are favorably located with respect to geologic structure and to texture of the bed, although the water-bearing properties are erratic.

A sample from well No. 544, approximately from the horizon of the Cassville shale, is dominated by the calcium (Ca), sodium (Na), and bicarbonate (HCO_3) radicles as shown by chemical analysis (p. 79), and carries 325 parts per million of dissolved solids. The water is moderately hard and otherwise of good quality for ordinary uses.

PENNSYLVANIAN SERIES—MONONGAHELA FORMATION

The uppermost subdivision of the Pennsylvanian series is the Monongahela formation, named for its development in the Monongahela Valley in the vicinity of Pittsburgh. This formation includes all strata between the top of the Waynesburg coal and the base of the Pittsburgh coal.

The Monongahela formation is on the whole rather calcareous in Pennsylvania. Nearly one-half its aggregate thickness is made up of beds of limestone, the remainder consisting of variable shales, discontinuous beds of sandstone, and persistent coal beds. Three of these coal beds are of great economic importance. As in the case of the overlying Permian rocks, individual members are quite variable in thickness and in local detail of lithology, though the formation as a whole is more regular.

The Monongahela formation varies in thickness between 260 and 400 feet within the region. It will be brought out in a subsequent paragraph that the formation was deposited upon an irregular erosion surface of the underlying rocks, so that the lower members are irregular in thickness. The Monongahela formation is thinnest in the northwestern part of the outcrop area along the Pennsylvania-Ohio boundary line; it thickens progressively southeastward more than 50 per cent in a distance of 60 miles and is thickest in Fayette County and in West Virginia. In the average section the thickness is 320 feet.

The Monongahela formation is widespread in the region south of the Allegheny-Ohio Valley and caps a very few of the highest hills farther north in the Mount Nebo, Nineveh, and McMurray synclines (Pl. I) of Allegheny County.

The Monongahela formation is not prominent as a source of ground water and in some localities fails to yield supplies of household magnitude. This is particularly unfortunate in that its outcrop area is a region of rather intense industrial development in which an abundance of ground water would serve many needs. The sandstone lentils and beds of the upper half of the formation are in general rather earthy and not highly permeable, although they yield small supplies in most places. Locally, these members are coarse grained and permeable and, where they lie below the plane of surface drainage, retain water under moderate head and yield freely to drilled wells. The sandstone members of the lower half of the formation are more uniform in water-yielding capacity. The limestone members yield moderately from minute bedding plane and joint passages to drilled wells and hillside springs, particularly along the axes and flanks of the synclines. Wells which reach the limestones below drainage level and at favorable locations yield as much as 25 gallons per minute. Where these beds lie above drainage level, however, they do not retain water under more than nominal head and the rate of yield is less than 5 gallons per minute. In extreme cases the rate of local recharge is less than the draft for household consumption so that wells may fail after a considerable period of use. Where beneath very deep cover the beds are not likely to be water-bearing. In general the limestone members are more important water-bearers than other parts of the formation, and this is particularly true of the persistent Uniontown and Benwood horizons.

In southern Allegheny County, Ohio River and its major tributaries have cut far below the base of the formation so that the lower members, particularly those which lie below the Benwood limestone, have been partially or wholly drained and do not constitute ground water reservoirs. Furthermore, subsidence of the roof above abandoned mine workings in the Pittsburgh coal, the lowermost member of the formation, has been followed by drainage of the overlying rocks. Hence, in several districts, successful wells can not be obtained. Where the formation lies beneath several hundred feet of cover, as in western Greene County, many deep wells find that it is not water-bearing throughout, although some other wells encounter ground water in permeable beds just above the Pittsburgh coal.

In general, wherever the Monongahela formation lies at or above drainage level the ground water is only fair in quality for most domestic and industrial uses, inasmuch as the relatively large content of

calcium (Ca) and bicarbonate (HCO_3) renders it objectionably hard. As the water percolates to deeper levels its calcium (Ca) content is replaced by sodium (Na), as described on pages 85-86, and it is softened thereby. The same process, however, causes it to foam more readily when used for boiler feed. Where the formation is more than 100 feet below drainage level its water is likely to be too highly concentrated to be desirable for most uses.

WAYNESBURG COAL

The type region of the Waynesburg coal is about Waynesburg, in eastern Greene County, where the bed attains a maximum thickness of 10 feet. Usually, however, it is 4 to 6 feet thick and varies widely in quality, being accompanied by one or more partings of clay and shale.

The Waynesburg coal is not known to be water-bearing in its type region, in which it is overlain by the very productive Waynesburg sandstone. To the north, however, in central Washington County. the sandstone is replaced by impermeable shales and the coal or the equivalent carbonaceous shale becomes a source of ground water locally. Typical wells are No. 356 of Chartiers Township, 1055 of Nottingham Township, 393 of Cokeburg Borough, and 400 of East Pike Run Township. The water in well 393 is reported to be at the bottom surface of the coal bed. The known productive localities are along the flanks or axes of synclines, above or at the plane of surface drainage, and not more than half a mile from the outcrop of the member. Under such conditions it seems that the coal serves as an impermeable confining bed and that local bodies of ground water become trapped above or below it according to the attitude of the bed with relation to the topographic slope. This horizon is not known to be a source of water beneath drainage level.

The chemical character of the water from the horizon of the Waynesburg coal is shown by analysis of No. 356, (p. 76), which represents a rather hard calcium-magnesium bicarbonate water of moderate concentration. The iron content, 1.3 parts per million, is sufficiently plentiful to be somewhat troublesome in causing stains on laundry and household utensils.

LITTLE WAYNESBURG COAL, WAYNESBURG LIMESTONE, AND ASSOCIATED ROCKS

The interval between the Waynesburg coal and the next persistent stratum, the Uniontown coal, is occupied generally by sandy shale and sandstone which, however, enclose one discontinuous bed of coal and another of limestone.

The beds which lie between the Waynesburg and Little Waynesburg coals are not productive of ground water, even the few sandstone lentils being argillaceous and impermeable.

From 1 to 15 feet below this local coal bed and 25 to 60 feet below the Waynesburg coal there is a heavy-bedded light-colored discontinuous limestone of fresh-water origin. This stratum, usually the only limestone between the Waynesburg and Uniontown coals, is known as the Waynesburg limestone. It is usually between 4 and 10 feet thick, although it is 20 feet or more thick at some places and is entirely absent at others. In northern Washington County, in western and

southern Greene County, and over most of Fayette County it is absent or represented by a nodular calcareous shale.

The Waynesburg limestone is the source of many small water supplies in the region of the Monongahela Valley. The developments in the southeastern quarter of Washington County are typified by wells No. 364, Carroll Township; 369, Washington Borough; 375, Fallowfield Township; 397, West Pike Run Township; and 406, Centerville Borough. For the contiguous area in northeastern Greene County, well 529 of Franklin Township, well 534 of Jefferson Township, and 538 of Carmichaels Borough are representative. The member also yields ground water to well 475 in the Port Royal syncline of Rostraver Township, Westmoreland County, and to well 616 in the Uniontown syncline of Georges Township, western Fayette County. Without known exception the ground water circulates through small passages in the soft calcareous shale which separates the limestone layers. In most instances the wells encounter water on the flanks of the folds and above the level of nearby surface drainage. No instances are known in which the member yields water where it lies more than 100 feet below drainage level, or at a locality much more than a mile down the dip from the outcrop. The yields obtained are small, few exceeding one gallon per minute from the Waynesburg limestone alone. Many wells, such as those representative of Greene County, are drilled to the underlying Uniontown limestone in order to obtain adequate and permanent supplies, and yet others pass entirely through the Waynesburg limestone without obtaining water. In most parts of the area water is confined under slight head only and rises in the well only 5 to 25 feet above the water-bearing bed. In general the Waynesburg limestone is not a prominent source of water.

UNIONTOWN SANDSTONE

A compact fine-grained flaggy to shaly sandstone which lies below the Waynesburg limestone in central Fayette and Westmoreland counties is known as the Uniontown sandstone. This bed is 10 to 20 feet thick. It is very variable and grades within short distances from a shaly thin-bedded member to a massive rock which is very similar to and has been mistaken for the overlying Waynesburg sandstone.

The Uniontown sandstone is generally dense and not highly permeable, although it yields small supplies at scattered localities in Westmoreland and Fayette counties in the region of relatively close folding. Of these, well 455 of Sewickley Township, Westmoreland County and 604 of North Union Township, Fayette County are representative. Along the eastern edge of this district, the sandstone is exposed at the steeply dipping flank of the Grapeville and Fayette anticlines, so that it can receive water along bedding-plane passages. The member is not known to be a water-bearer below drainage level. The outcrop of the Uniontown sandstone horizon is also the locus of many small hillside springs in this region, No. 493 of Mount Pleasant Township, Westmoreland County, being typical. An abundance of such springs should not be accepted, however, as an indication that the member is everywhere highly permeable beneath cover. Rather, these springs indicate that the sandstone, together with the underlying Uniontown coal, has a low permeability locally, that it retards or arrests the downward percolation of suspended water through the

disintegrated beds above, and that, consequently, it induces lateral migration of the water toward the outcrop and favorable points of discharge.

In central Washington County the horizon of the Uniontown sandstone was found to be water-bearing at a depth of 100 feet below the surface by well 387 of Amwell Township. The locality is approximately half a mile west of the axis of the Amity anticline. The well was continued down to the Sewickley sandstone, which was reached at a depth of 172 feet below the surface, without establishing the water yielding capacity of the Uniontown member. Inasmuch as there is no other known instance of this member being a water-bearer at any point west of the Monongahela River, its value as a potential source is problematic.

UNIONTOWN COAL

Close below the Uniontown sandstone or its horizon and 40 to 110 feet below the Waynesburg coal is the Uniontown coal. This bed attains a maximum thickness of 3 feet near Uniontown; elsewhere it is usually 12 to 20 inches thick and in many localities is represented only by a bituminous or carbonaceous shale.

UNIONTOWN AND BENWOOD LIMESTONES

Beneath the Uniontown coal, and separated from it by not more than a few feet of shale, is a group of limestone beds interstratified with shale and local sandstones. In the average section its top is 55 feet below the Waynesburg coal and its thickness is about 110 feet.

This group is made up of the Uniontown limestone about 30 feet thick, 15 to 20 feet of coarse calcareous shale, the Fulton shale, and the Benwood limestone from 60 to 100 feet thick.

The interval between the Uniontown and Benwood members is in most places filled with shale, although where the horizon crops out in Fayette and Westmoreland counties a bed of variable sandstone is frequently seen. This sandstone attains a thickness of 20 to 30 feet in the region about Greensburg, where it is quarried at several places for road metal and heavy masonry. It has recently been termed the "Bench" sandstone.

The Benwood limestone is somewhat more continuous than the overlying Uniontown member. In the western part of the region, in Fayette, Washington, and Allegheny counties, its maximum thickness is about 105 feet. In Fayette and southern Westmoreland counties to the last the Benwood limestone is 60 to 80 feet thick, but it thins northeastward and is but a few feet thick in Derry Township of Westmoreland County. The beds which constitute the member are generally less than 2 feet thick, though locally they are as much as 10 or 12 feet.

The Uniontown and Benwood limestones, together with the interlaminated calcareous shales, yield many small water supplies throughout the outcrop area of the Monongahela formation. As in the case of the limestone members of the overlying Permian rocks, circulation takes place through small bedding plane passages—largely in the laminae of calcareous shale, by means of joint cracks, or at the upper surface of the member. The Uniontown and Benwood limestones, however, are water-bearing throughout much of the region and not merely

in the vicinity of the outcrop. This is due in large measure to the relative competence of these thick limestone members, as a result of which they were fractured extensively during the mountain-building epoch. Subsequently, circulating ground waters entered the joint planes, probably enlarged them somewhat by solution, and created other solution passages along bedding planes in the shale laminae. This action has extended many miles from the region of outcrop, so that the members have a relatively large water-yielding capacity even where they are as much as 100 feet below drainage level. To what extent the members may be water-bearing at even greater depths is largely speculative, although the records of deep wells in western Greene County along the flanks of the Nineveh syncline, fail to report the occurrence of water at this horizon.

Springs of variable flow, which yield a few gallons per minute, are numerous along the outcrops of these limestone members. Many of these springs are true joint or bedding plane springs supplied by a distant source and, hence, are indices of the water-yielding capacity of the beds. Others, those whose flow is most variable, presumably originate locally in vadose water trapped above one of the impermeable limestone beds. Such springs do not indicate the water-bearing properties of the rocks beneath cover. Drilled wells which reach the Uniontown and Benwood limestones between depths of 30 and 150 feet are usually successful, particularly along the axes and flanks of the synclines (Pl. I). Where the members lie far above the plane of surface drainage, water is retained under nominal head only and the yield ranges between a small fraction of one gallon and four gallons per minute. At greater depths however, the members are saturated at most places, the static level is not more than 25 feet below the plane of surface drainage, and the yield approaches the maximum of 25 gallons per minute.

The Uniontown and Benwood limestones crop out extensively in southern Allegheny County, where they have been cut through by Ohio River and its major tributaries. In this district the yields are small and erratic as to location and a considerable proportion of the wells are unsuccessful. Conditions are typified by No. 314 of South Fayette Township, and No. 321 of Elizabeth Township. At site No. 314 a well was drilled through the horizon of the limestones to the base of the Pittsburgh coal, which was reached at a depth of 206 feet. This well supplied natural gas from the coal for a year, before it was drowned out by the slow influx of water. A second well drilled at a site 100 feet away and at a somewhat higher elevation, developed a yield of a third of a gallon per minute at the horizon of the Uniontown limestone and 79 feet below the surface. An effort to increase the yield by shooting 20 sticks of dynamite in the well resulted disastrously, inasmuch as the water was perched 100 feet above drainage level and the crevices opened by the explosion drained the well completely. Well 321 developed a yield of approximately one gallon per minute, whereas a well at a nearby sectarian school passed through the limestones, encountered the Pittsburgh coal 250 feet below the surface, and bottomed at a total depth of 305 feet without finding water. In well 1028, Scott Township, 61 feet of 16-inch casing was set to exclude water, the rate of yield not being reported. This casing would reach a horizon somewhat below the Uniontown limestone, a fact sug-

gesting that member to be the source. Such casing practice is not usual however.

The water-yielding capacity of the Uniontown and Benwood limestones in Washington County is adequately represented by wells 339, Smith Township; 342 and 1049, Jefferson Township; 344, Cross Creek Township; 346, Mount Pleasant Township; 349, Cecil Township; 353, Peters Township; 1056, Nottingham Township; 374, Bentleyville Borough; 389, Amwell Township; and 405, Centerville Borough. Particular attention is called to the three wells at site 389, at the Lone Pine compressing station of the Carnegie Natural Gas Company. This site is 0.2 mile west of the axis of the Amity anticline and 10 miles from the nearest outcrop of the bed. On pumping by means of gas lift during a capacity test of 72 hours duration, two of these wells yielded at respective rates of 21 and 23 gallons per minute. The drawdown is reported to have been only a few feet. The capacity of the third well was not determined but was estimated to be approximately equal to either of the other two. The chemical character of the water from the wells is discussed in a subsequent paragraph.

For Westmoreland County. conditions are depicted by wells 428 of Penn Township; 451 and 452, Sewickley Township; and 490, 494, and 499, Mount Pleasant Township. In this county the member forms many scattered outcrops, and its water-bearing properties vary somewhat erratically from place to place. Along the axes of the deep synclines, however, these limestones yield copiously to wells when they lie below drainage level.

In Greene County the Uniontown and Benwood limestones lie below the maximum depth of feasible development except in the extreme eastern part along the Monongahela River. Typical wells are 517 of Morgan Township, 535 of Jefferson Township, 537 of Cumberland Township, 545 and 548 of Monongahela Township, and 564 of Dunkard Township. At site 548 a well penetrates the water-bearing Benwood limestone 110 feet below the surface and enters an abandoned mine entry on the Pittsburgh coal seam at a depth of 250 feet below the surface. Water is stored in a cistern constructed in the mine entry beneath the boring and is piped therefrom to the miners' dwellings on the hillside below.

In Fayette County, as in Westmoreland County to the north, the Uniontown and Benwood limestones are cut through by many of the streams, so that their water-bearing properties vary from place to place, depending upon the attitude of the beds with relation to the topographic surface. In the major synclines, however, the members are extensive over many square miles and yield copiously when below drainage level. Wells 586 of Dunbar Township, 593 of Brownsville Borough, and 598 of Redstone Township are typical.

The chemical nature of the water from the Uniontown limestone is shown by the analyses of samples from two wells in Washington County, Nos. 346 of Mount Pleasant Township and 389 of Amwell Township. No. 346 represents a moderately concentrated calcium bicarbonate water which is rather hard but is otherwise of good quality for domestic purposes. It would be somewhat troublesome as a scale-former if used for boiler feed without treatment. This sample represents the chemical nature of the water where the limestone is above the level of nearby creeks. Analysis No. 389, on the other hand, repre-

sents a highly concentrated water that has been almost completely softened by the process of base exchange (see pp. 85-86); it is from a well that reaches the water-bearing stratum about 60 feet below drainage level. This water is so highly concentrated that it is somewhat undesirable for domestic use and most industrial purposes. Analysis No. 389 also represents a soft sodium bicarbonate water to which considerable sodium chloride has been added. Locally, in the vicinity of Canonsburg and Houston, in the north-central part of Washington County, the Uniontown limestone yields a relatively salty water.

SEWICKLEY SANDSTONE

The Sewickley sandstone where present lies between the Benwood limestone and Sewickley coal. At the Big Falls of the Monongahela River it is flaggy to massive sandstone 20 to 60 feet thick. It is not present in the Latrobe syncline of north central Westmoreland County, and is also absent at the one outcrop which exposes its horizon in southwestern Washington County. It crops out in central Westmoreland County in the vicinity of Greensburg, however, and at this locality is massive to even bedded and is quarried for local use. The horizon of this bed is beneath cover in the greater part of the region and, in the absence of complete and detailed well records, its extent can not be delineated completely.

The Sewickley sandstone is a source of water in central Washington County and in the extreme northwestern portion of Fayette County, although nothing is known of its water-bearing properties elsewhere. Of the Washington County district, wells 368 of Washington Borough and 387 of Amwell Township are typical. These are located near the southward-plunging axes of the Washington and Amity anticlines, respectively, which structures bring the sandstone within 200 feet of the surface. In this district the sandstone is coarse-grained and moderately permeable. Well 387, for example, has a specific capacity of 0.6 gallon per minute for each foot of drawdown, although it derives an unknown but probably minor portion of its yield from the overlying Waynesburg and Uniontown sandstones. Water is confined in the member under considerable hydrostatic pressure and rises nearly to the plane of surface drainage. In northwestern Fayette County, however, the member is more variable in lithology and is much less productive. Conditions are represented by wells 568 of Perry Township and 582 of Jefferson Township, both of which are on the flank of the Port Royal-Lambert trough (Pl. I). Water is retained under nominal head only and the yields range from a fraction of a gallon to perhaps five gallons per minute.

While drilling well 1028, Scott Township, southwestern Allegheny County, it was necessary to set 134 feet of 8¼-inch casing to exclude ground water. This casing was landed slightly below the horizon of the Sewickley sandstone, a fact which suggests that member to be water-bearing. However, the lithology of the member and its rate of yield at that locality were not recorded.

The quality of the water from the Sewickley sandstone below drainage level is shown by the analysis of a sample from well 368 (p. 76). This is a rather highly concentrated sodium-bicarbonate water that is not satisfactory for domestic or for most industrial uses. Water

from this sandstone may, however, be valuable for condensing or cooling. Where the member is above drainage level the water is likely to be much better than that from well 368 but the quantity is not great.

SEWICKLEY (MAPLETOWN) COAL

The first bed below the Uniontown coal which is a trustworthy horizon marker over extensive areas is the Sewickley coal. This bed is 185 to 300 feet below the Waynesburg coal, and 80 to 150 feet above the base of the Pittsburgh coal. The Sewickley coal is thickest in the south central part of the area, its thickness ranging from a few inches to 6 feet. In some areas the Sewickley coal is represented by 1 to 3 feet of bituminous shale.

So far as is known the Sewickley coal does not supply any water well within the region, although the logs of several gas wells drilled in central and southern Greene County report the occurrence of water at that horizon. Wells 1078 of Center Township, 1096 of Wayne Township, and 1099 of Perry Township are typical. The yield, however, does not exceed one gallon per minute. It is conceivable that this water exists, not in the Sewickley coal itself, but rather in the lower part of the overlying Sewickley sandstone or the equivalent beds.

FISHPOT LIMESTONE AND ASSOCIATED BEDS

Beneath the Sewickley coal is a group of sandy shales or sandstone 40 to 60 feet thick which encloses a discontinuous limestone near its center. This discontinuous bed was formerly called Sewickley limestone but is now known as the Fishpot limestone, from the type locality at the mouth of Fishpot Run, in southeastern Washington County. It is 30 feet thick at the type locality and 20 to 30 feet thick in the vicinity of Washington, but thins radially. It is thin and discontinuous in the northern part of Washington County and adjacent parts of Allegheny County, and to the east in Westmoreland and Fayette counties. In Greene County and the southwestern part of Washington County it is under cover at most places so that its thickness can not be observed.

The type phase of the Fishpot limestone is a local source of ground water along the flanks of synclines in the more closely folded terrane of central and southwestern Westmoreland County. Wells 448 of North Huntingdon Township and 463 of Hempfield Township are typical. In this district the member is generally fractured and gives domestic supplies where it lies below drainage level, but the yield is likely to be only a fraction of a gallon each minute where it occurs above drainage level. In general, however, this type phase is not water-bearing inasmuch as it lies for the most part beneath cover and has not been exposed to the solvent action of circulating ground water.

The sandy shale and shaly sandstone which accompany and locally replace the Fishpot limestone yield many small supplies in northern Washington County, chiefly along the axes and flanks of synclines (Pl. I). For this district, which is relatively close to the outcrop of the Fishpot limestone, wells 340, Smith Township; 350, Cecil Township; 1502, Peters Township; and 362, Union Township are representative. In west-central Fayette County, along the Monongahela River, this horizon also is within reach of the drill, as shown by

well 595 of Luzerne Township. Most of the wells which reach this horizon are successful in developing supplies of household magnitude, although the inflow to the well is seldom more than one or two gallons per minute. A few wells are unsuccessful. Water is not retained under great head, so that many of the wells which are supplied by this member must be drilled below the water-bearing stratum in order to provide storage volume. Farther south, the shaly and sandy facies of the Fishpot limestone are much inferior in water-yielding capacity to overlying beds and, hence, are not a potentially valuable source. To the north, in southeastern Allegheny County, the lower beds of the Monongahela formation have been cut through by the major streams and, consequently, have been drained in large part. In this district, the Fishpot limestone is so impermeable that it supports local perched bodies of ground water, such as those encountered by wells 310 of Mifflin Township and 319 of Elizabeth Township. In most places, however, the Fishpot limestone is not a source of ground water.

REDSTONE COAL AND REDSTONE LIMESTONE

The Redstone coal is a moderately continuous bed which lies 20 to 85 feet above the Pittsburgh coal, the interval varying greatly even within small areas but increasing progressively eastward.

The Redstone coal is not in general water-bearing, although in some instances the beds just above or below are productive and it has been assumed that the coal is the source.

The Redstone limestone varies from a few feet to 25 feet in thickness, and in general is thickest where the underlying Pittsburgh sandstone is thinnest and is absent where the Pittsburgh sandstone is thickest.

The Redstone limestone member is a source of small water supplies in the vicinity of its outcrop and along the flanks of the synclines (Pl. I) in northern Washington County, in southwestern Allegheny County, and along the Monongahela Valley of Fayette and Westmoreland counties. Nothing is known of its water-bearing properties in the Greensburg and Uniontown-Latrobe synclines to the east. Farther south the member passes beneath continuous cover of younger rocks and is a potential source of water. Typical wells are Nos. 338, 341, and 1048 of Smith Township, Washington County; 479 of Rostraver Township, Westmoreland County; and 566 of Washington Township, Fayette County. In this limestone water circulates through small solution passages, chiefly in the laminae of soft calcareous shale which separates the limestone layers. Where the limestone lies above drainage level, its yield is small and recharge may be less than the draft so that wells may fail after long use. Where it lies at or slightly below drainage level, however, the member yields several gallons per minute. Inasmuch as several of the overlying members are superior sources of water, few if any wells are drilled to the Redstone limestone where it lies more than 50 feet below drainage level in the synclines. Hence its water-yielding capacity at depth is not known.

The chemical character of the water from the Redstone limestone where it lies above drainage level is indicated by analysis 479. This is a moderately concentrated calcium-magnesium bicarbonate water that is too hard to be desirable for household use or for boiler feed without previous softening.

PITTSBURGH SANDSTONE

The interval between the Redstone and Pittsburgh coals is in many places occupied in whole or in part by the Pittsburgh sandstone, which has also been called Upper Pittsburgh. This bed is typically coarse-grained, massive to irregularly-bedded, friable, and buff to dark gray or brown in color. In many localities however, it grades laterally into flaggy or thin-bedded sandstone and into interbedded sandy shales and sandstone lentils. The Pittsburgh sandstone varies in thickness from zero to 70 feet, and generally thickens toward the south.

The Pittsburgh sandstone and its equivalents are highly permeable over wide areas, but they have been drained rather completely wherever the underlying Pittsburgh coal has been mined and the roofs above the abandoned mine entrys have collapsed. Consequently, this sandstone is no longer a potential source of water in many of the mining districts, especially in those which have long been worked out and abandoned, as in southern Allegheny County. Furthermore, such drainage is likely to become more extensive in the future. In some places, the muddy water which percolates down from the surface along the larger subsidence fractures or ''breaks,'' puddles the drainage conduits so that the sandstone may become water-bearing again after a lapse of several years. It is quite by chance, however, that such puddling takes place and in most districts the water-yielding capacity of the sandstone is never fully restored. In those districts in which the coal has not been mined, the member displays its normal water-bearing properties. In many mining districts also, roof collapse has not been general and the member has not been completely drained, so that wells of moderate yield may be obtained if care is taken to cease drilling before the well penetrates the mine entry.

The type phase of the Pittsburgh sandstone, especially its lower portion, supplies many drilled wells and its outcrop is marked by numerous hillside springs in the northern half of Washington County and in western Fayette and Westmoreland counties. Typical wells and springs are No. 329 of Hanover Township and 370 of Washington Borough in Washington County; 476 of Rostraver Township and 488 of South Huntingdon Township in southwestern Westmoreland County; also 614 of Nicholson Township in southwestern Fayette County. Where the member lies below drainage level it is likely to be saturated, the head to be moderately high, and the yield moderately large. The yield of well 614, however, is reported to be but 5 gallons an hour, the water-bearing stratum being entered high on the flank of the Fayette anticline (Pl. I) and far above drainage level.

The shaly facies of the Pittsburgh sandstone horizon is a rather persistent source of small or moderate water supplies throughout most of the area. Representative wells in southern Allegheny County are No. 315 of Snowden Township, and 321 and 322 of Elizabeth Township. In northern Washington County 328 of Hanover Township, 337 of Smith Township, and 1054 of Peters Township are typical. Wells 450 of Sewickley Township, Westmoreland County and 625 of Springhill Township, Fayette County are also representative. Yields range from a fraction of a gallon to 35 gallons per minute, the maximum being attained where the member lies below drainage level on the flanks of a syncline.

The summation of experience in drilling many deep wells for oil and gas in the region southwest of the Ohio and Monongahela rivers has been that the lowermost beds of the Monongahela formation are frequently water-bearing. Consequently it has become a standard practice to set casing when the well is not more than 50 feet below the Pittsburgh coal in order to exclude water. The examples which are tabulated below, suggest the depths at which these beds—which include the horizon of the Pittsburgh sandstone—may have been water-bearing, although the rate of yield is not reported. The composition of the water is not known, although it is likely to be highly concentrated and saline at the greater depths.

Amount of casing set in representative deep wells to shut off water-bearing beds in lowest part of Monongahela formation.

No. on Figs. 35, 38, 39	County	Township	Depth reached by casing (feet)
1028	Allegheny	Scott	245
1037	Allegheny	Snowden	182
1053	Washington	Peters	225
1082	Greene	Jefferson	376
1090	Greene	Whitely	678
1095	Greene	Wayne	967
1097	Greene	Perry	856
1098	Greene	Perry	790

Furthermore, it is reported that some of these deep wells encountered water at the top of or with the Pittsburgh coal, typical examples being No. 1078 of Center Township, 1096 of Wayne Township, and 1099 and 1100 of Perry Township, Greene County. The experience of mining has been, however, that the coal itself is not usually water-bearing. It seems, therefore, that the souree-bed is more likely to be the lowermost part of the Pittsburgh sandstone horizon.

The water obtained from the Pittsburgh sandstone at or above drainage level is somewhat softer than that from the limestone members of the Monongahela formation and hence is more desirable for domestic uses. Locally the eontent of dissolved iron is sufficiently large to be troublesome in staining linens during laundering and in depositing a sludge of iron oxide in pipes and vessels. Where the member lies from 50 to 100 feet below drainage level, as in well 315 of Snowden Township, Allegheny County, the water is likely to be soft. In such cases the water foams when used in boilers. Where the member lies beneath several hundred feet of cover, its water is probably a very concentrated brine and unfit for most uses.

PITTSBURGH COAL

The well-known Pittsburgh coal, whose base marks the bottom of the Monongahela formation, is the most uniform and most valuable coal bed of southwestern Pennsylvania. Its thickness is usually between 4 and 14 feet, including shale partings, although locally it exceeds 20 feet.

The Pittsburgh coal bed is perhaps the most uniform and persistent stratum of the Carboniferous system and serves as an ideal key bed in tracing the geologic column and structure. For this reason it has become the standard reference surface for the correlation of strata

throughout its outcrop area and wherever it has been penetrated by the drill. The trace of its outcrop is shown on the geologic map (Pl. I) by the boundary between the Monongahela and Conemaugh formations.

CONEMAUGH FORMATION

The Conemaugh formation differs from the overlying Monongahela formation in being much less calcareous and carbonaceous and even more irregular in detailed stratigraphy. The upper portion embraces gray and green shales, locally variegated, with several thin and discontinuous sandstones and limestones and local beds of coal. Red shales are abundant, and occupy no definite stratigraphic position. The lower 200 feet of the formation, on the other hand, is made up largely of sandstones, locally massive, which enclose relatively thin beds of shale and discontinuous thin beds of coal. None of the beds are sufficiently persistent to serve as key horizons throughout the outcrop area of the formation, although the limestones may be used in most places in conjunction with other associated beds. Several of the sandstone members persist over wide areas, but are subject to such large and abrupt changes in thickness that they are untrustworthy guides to the stratigraphy.

Within the region covered by the report, the Conemaugh formation ranges in thickness from 500 feet along the Ohio River northwest of Pittsburgh to 750 feet in the Latrobe syncline of Westmoreland County. Although there are local irregularities, the interval increases progressively eastward about 50 per cent in the horizontal distance of 55 miles. The rate and direction of this thickening are the same as for the overlying formations.

The Conemaugh formation is an outstanding source of water. its sandstone members—the Connellsville, Morgantown, Saltsburg, Buffalo, and Mahoning sandstones—being especially productive over extensive areas. In general, water occurs in coarse-grained highly permeable zones of the member, which yield to drilled wells at rates as large as 100 gallons per minute where the member lies below drainage level. Where they lie above drainage level, however, the permeable layers may not be fully saturated and the yield to wells may be only one or two gallons per minute. Moreover, these coarse-grained facies are discontinuous, so that the water-yielding capacity of the members varies greatly from place to place. Locally, the massive phases of these members have been extensively fractured during crustal deformation, especially along anticlinal axes (Pl. I), and the joint planes serve as conduits for ground water circulation. The shale members of the formation, together with the shaly facies of the several sandstones, yield household supplies from minute bedding plane passages and from joint planes, chiefly where they lie above drainage level along the flanks of the folds. On the whole, however, they are relatively impermeable and the yield to wells rarely exceeds 5 gallons per minute, and in many wells is but a fraction of one gallon per minute. At places where the geologic structure is favorable, these slightly permeable members also enclose scattered perched bodies of ground water. Where these shaly beds pass beneath unbroken cover the bedding plane conduits are generally closed and the beds are not a source of water. The few limestone members of the Conemaugh are both thin and discontinuous and are not important as water-bearers. Locally, however, along the

flanks of folds they serve as restraining beds so that water is trapped close beneath or, less frequently, above them.

In many districts, however, the Conemaugh formation is dry, either wholly or in part. This is especially true of the impermeable shales and shaly facies of the sandstone members of the upper half of the formation, which do not yield water beneath deep cover, as in wells 295 of Penn Township and 319 of Elizabeth Township, Allegheny County; and in well 460 of Adamsburg Borough, Westmoreland County. Similar conditions prevail generally in the region. Hence, it has been common experience that wells which start in the lower part of the Monongahela formation and pass through the Pittsburgh coal at a distance from the outcrop, do not find water within the maximum practicable depth. In other localities the formation is dry except the zone of weathering, as in wells 1021 of Findley Township, Allegheny County; 1044 of Hanover Township, and 1049 of Jefferson Township, Washington County; also 605 of North Union Township, Fayette County. At Renton, in east-central Allegheny County (Fig. 35, No. 299), the shaft of the Union Collieries Coal Co. reaches the Upper Freeport coal at a depth of 509 feet and encounters very little ground water. Furthermore, the casing practice which prevails in the gas fields of the southwestern part of the region suggests that the Conemaugh formation usually does not yield more water than is needed for drilling. Typical wells of this sort are No. 1028 of Scott Township and 1037 of Snowden Township, Allegheny County; 1053 of Peters Township, Washington County; 1082 of Jefferson Township, 1090 of Whiteley Township, 1095 of Wayne Township, 1097 and 1098 of Perry Township, Greene County. Locally, the collapse and subsidence of the roof above abandoned entries along the Upper Freeport coal has induced drainage of the overlying basal members of the Conemaugh formation so that they are not a source of water supplies.

The waters from the Conemaugh formation show a wide range in chemical character, the representative samples to which reference is made on subsequent pages including the least concentrated, and, with the exception of the brines encountered by deep oil or gas wells, the most highly concentrated of all samples from the entire area. The extremes are 8,595 and 62 parts per million f dissolved solids. Furthermore, they include the extremes in hardness of all waters sampled, the maximum being 1,843 parts per million and the minimum 13 parts per million. In general, however, the waters contain from 200 to 500 parts per million of dissolved solids and the hardness is from 100 to 300 parts per million, so that the waters are of fair quality for most uses. Under given conditions, the waters of the lower members of the formation are in general less concentrated, although the proportionate amounts of the several constitutents vary but slightly.

UPPER AND LOWER PITTSBURGH LIMESTONE AND LOWER PITTSBURGH SANDSTONE

The uppermost 50 feet of the Conemaugh formation consists of light yellow sandy or clayey shale with which several red shale bands and two or more discontinuous limestones are interbedded. The limestone beds are usually not more than a few feet thick. At many places in the region, especially in the northern part, a thin impure coal

is occasionally found above the Lower Pittsburgh limestone. This is known as the Lower Little Pittsburgh coal.

In a few localities the shale and limestones beneath the Pittsburgh coal are replaced in whole or in part by a flaggy sandstone, to which the name Lower Pittsburgh sandstone has been applied. In most places this bed is 20 feet or more thick, and in a few localities it is united with the underlying Connellsville sandstone member to form a single bed 80 feet thick.

The Lower Pittsburgh limestone and its associated varicolored shales yield the only available domestic water supplies at many of the mines on the Pittsburgh coal. Typical wells in Allegheny County are No. 293 of Penn Township, 1021 of Findley Township, and 306 of North Fayette Township. In Washington County, wells 331 of Robinson Township and 399 of West Pike Run Township are representative. Others are No. 426 of Franklin Township, 432 of Salem Township, and 433 of New Salem Borough, in Westmoreland County; also 567 of Washington Township and 624 of Springhill Township, Fayette County. The shaly facies of the horizon is also productive, as typified in Allegheny County by wells 287 of Robinson Township; in Washington County, by 327 of Hanover Township, 333 and 336 of Smith Township, and 363 of Union Township; in the Monongahela Valley of eastern Greene County by 546 of Monongahela Township; and in Fayette County by 580 of Jefferson Township, and 613 of Nicholson Township. The Little Pittsburgh coal is reported as a source of water in well 477 of Rostraver Township, Westmoreland County.

The beds of this horizon are not permeable under ordinary pressure except as small bedding plane passages have been formed by solution of the soft calcareous shales. This process has been most active in the vicinity of the outcrop and along the flanks of folds, but has not progressed beneath deep cover. Under such conditions these members yield many small supplies of erratic location near their outcrops, but they are not usually water-bearing where they lie more than 50 feet below the plane of surface drainage. Hence it follows that wells which are unsuccessful in the lower part of the Monongahela formation and pass through the Pittsburgh coal at a distance from the outcrop, usually fail to develop water in these beds. The rate of yield is variable, the recorded maximum for drilled wells which find the member below drainage level being 15 gallons per minute; usually however, it is much less. The hydrostatic head is small.

In general, the water obtained from these beds is objectionably hard and in many instances contains sufficient iron in solution to stain linens and cooking utensils. Locally also, a slight quantity of hydrogen sulphide gives the water a disagreeable odor, although this constituent is not physically harmful and passes off when the water is boiled or is allowed to stand in contact with the atmosphere. Analyses 331, 433, and 567 (pp. 75, 77, 80) represent moderately concentrated and rather hard calcium bicarbonate waters from the limestone members. Sample 567 contains so much hydrogen sulphide (H_2S) that its dissolved iron separates out as a very fine suspension of bluish black ferrous sulphide (FeS) after the water has been pumped and allowed to stand in contact with the air about five minutes. Analyses 333 and 336, on the other hand, represent calcium-magnesium sulphate waters from the red shale members. The water from these shales is moderately to very

highly concentrated and very hard. Some of it, such as the water represented by analysis 333, is unfit for any ordinary use. In the vicinity of Canonsburg and Houston, in north-central Washington County, salt water is usually found in the upper part of this group of beds and close beneath the Pittsburgh coal. In a few instances, as in that of well 581 of Jefferson Township, Fayette County, the water is quite non-potable where the member lies below regional drainage level.

CONNELLSVILLE SANDSTONE

The first persistent stratum beneath the Pittsburgh coal is the Connellsville sandstone, named from the region about Connellsville, in north-central Fayette County, in which it occurs with typical texture and thickness. The top of this member is 30 to 60 feet below the base of the coal in Fayette and southern Westmoreland counties. The Connellsville sandstone is coarse or medium-grained, micaceous, thin-bedded or locally massive; it grades laterally into gray and red sandy shale, which in most places is cross-bedded. The member ranges in thickness from a few feet to 80 feet, although where it is thickest the upper portion is possibly contemporaneous with the Lower Pittsburgh sandstone. It is present in the Uniontown syncline of Fayette County at almost every locality its horizon is exposed, although farther north in Westmoreland County it is intermittently shaly in the Latrobe syncline and the Ligonier Valley. The Connellsville sandstone is less persistent and almost always thinner than the underlying Morgantown and Saltsburg sandstones.

The Connellsville sandstone is coarse-grained and moderately permeable in southwestern Allegheny County and near by parts of Washington County. To the west it becomes somewhat shaly and an inferior source of water. Little is known about the texture of the member beneath deep cover to the southwest, although the records of deep wells fail to note it as water-bearing and thereby suggest that it is fine-grained and relatively impermeable. Typical developments in Allegheny County are wells 278 of Moon Township, 283 of Findley Township, 294 and 295 of Penn Township, 297 of Plum Township, 301 of Patton Township, 307 of North Fayette Township, and spring 311 of North Versailles Township. Those for Washington County are 1043 of Hanover Township, 332 and 1045 of Robinson Township, 335 of Smith Township, 355 of Independence Township, 1053 of Peters Township, 360 of Union Township and 377 of Speers Borough. In the northern part of the district, where the member is cut through by surface streams, its adequacy as a source of water depends upon the dip of the bed with reference to the topographic surface and the yield to wells may be a fraction of a gallon each minute. Southward the member passes below drainage level and retains water under moderate hydrostatic pressure and hence displays a rather uniform water-yielding capacity. Drilled wells in the southern part of the district yield as much as 25 gallons per minute from the Connellsville sandstone without depletion.

Well 360, located half a mile east of the axis of the Amity anticline in northeastern Washington County (see Pl. I and Fig. 39), flows slightly by artesian pressure, the southward-plunging axis serving as an artesian slope. The area of artesian flow is not large, however, and is probably limited to the bed of Peters Creek and its tributaries in the vicinity of the anticline axis.

The Connellsville sandstone is also moderately permeable in the Monongahela Valley at well 402 of East Pike Run Township, southeastern Washington County. Farther south, at well 565, in Dunkard Township of extreme southeastern Greene County, it is somewhat shaly and its water-yielding capacity is moderate.

The Connellsville sandstone is a prominent water-bearer in the lower Youghiogheny Valley region of Westmoreland County, representative wells being 454 of Suterville Borough and 478 of Rostraver Township, 480 of West Newton Borough, and 482 and 485 of South Huntingdon Township. In this district the basal portion of the member which is coarse-grained at many places is the most productive horizon. The water-yielding capacity varies locally and at times abruptly, however, a fact which suggests equal variability in other districts. For example, it is reported that the sandstone passes abruptly into an impermeable red shale 200 yards upstream from site 454 at Suterville. This lateral change cannot hold over an extensive area, however, for the West Newton municipal wells, No. 480, find the member to have its typical coarse texture about 3 miles to the southeast. Furthermore, at the American Reduction Co. plant, site 485, the ratio between the maximum and minimum reported yields of five wells is as 10 to 1.

In central Fayette County the Connellsville sandstone occurs in type phase and is water-bearing in the axial portion of the Uniontown syncline (Pl. I). Frequently in this region it is known to the drillers as the Murphy sand, being confused with the Morgantown sandstone. Its water-yielding capacity is indicated by wells 576 of Bullskin Township, 585 of Vanderbilt Borough, and 619 of Smithfield Borough. On the flanks of the fold the member rises far above drainage level and yields very sparsely or not at all, as in wells 601 of North Union Township and 622 of Georges Township. In the northward extension of this same trough, in the Latrobe syncline of central Westmoreland County, the member becomes shaly and not highly permeable, although it is a source of water locally as at wells 436 of Derry Township and 472 of Unity Township.

The water from the Connellsville sandstone is shown by analyses 307, 332, 480, and 576, and by the accompanying diagram (Fig. 26) to be moderately to highly concentrated. Nos. 307 and 360 are rather hard calcium bicarbonate waters where the member lies at or above drainage level. Nos. 332 and 480, on the other hand, are waters that have been partly softened by the process of base exchange (see pp. 85-86). In most districts the iron content of the water is low, but locally, where the member is above drainage level, it is sufficiently high to stain linens during laundering and form a troublesome sludge in the well or in household receptacles. This is true of well 307, in which a sludge of iron oxide is reported to form in such abundance as gradually to close the interstices of the water-bearing stratum. Consequently it is necessary to shoot and clean the well about once in three years to mainatain its water-yielding capacity.

LITTLE CLARKSBURG COAL AND CLARKSBURG LIMESTONE

The interval extending from the Connellsville sandstone to the next persitent stratum below is occupied by greenish-gray and red shales which enclose the Little Clarksburg coal and the Clarksburg

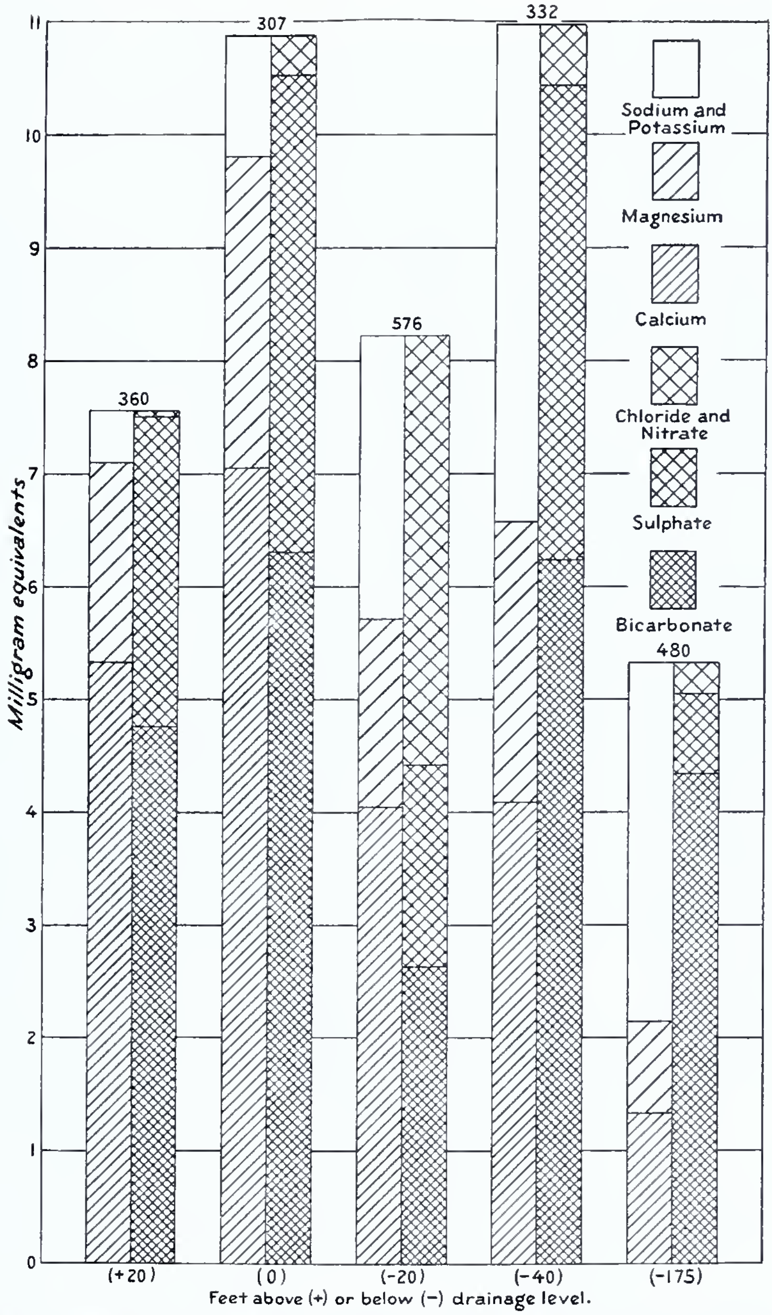


Figure 26.—Relation between quality of waters from the Connellsville sandstone and distance of that stratum above or below nearby surface streams.

limestone of Washington County. The Little Clarksburg coal is thin and discontinuous, extremely variable in quality and thickness. So far as is known it is found only in northern Washington County, eastern Allegheny County, and adjacent areas. The Clarksburg limestone lies just below the Little Clarksburg coal where that bed is present, being 75 to 90 feet below the Pittsburgh coal in Washington County and 100 to 160 feet below in central Westmoreland County. In most places the limestone is less than 3 feet thick.

Although red shale may occur in any part of the Conemaugh formation from a horizon 30 feet below the Pittsburgh coal down to the top of the Mahoning sandstone near the base of the formation, such beds are especially abundant at the horizon of the Clarksburg limestone. These red shale members are in general lenticular and discontinuous in the extreme.

The Little Clarksburg coal is not in general a source of water, although well 279 of Stowe Township, southwestern Allegheny County derives an ample household supply from carbonaceous shale which is probably the equivalent of the coal.

The Clarksburg limestone is a source of small seattered bodies of ground water in the northern part of Washington County, in the Duquesne and Port Royal synclines (Pl. I) of eastern Allegheny County and west-central Westmoreland County, and in the southern portion of the Uniontown syncline of Fayette County. Wells 1044 of Hanover Township, 347 of Mount Pleasant Township, and 357 of Chartiers Township are typical for Washington County. Others are No. 300 of Plum Township, Allegheny County, as well as 429 of Penn Township and 460 of Adamsburg Borough in Westmoreland County. For Fayette County, wells 622 of Georges Township and 623 and 626 of Springhill Township are representative. As in the case of the overlying limestone, ground water circulates through small solution passages which follow bedding planes and joints. Where the member lies above drainage level, it yields less than one gallon a minute to wells at most places and is entirely dry over extensive areas. Below drainage level, the member is saturated, retains water under small head, and at most places yields from 1 to 5 gallons per minute. However, well 300, which is on the flank of the Duquesne syncline in eastern Allegheny County, is reported to have yielded 100 gallons a minute for periods of as much as 48 hours duration in the summer of 1926. This well is in the bed of Plum Creek, tributary of Allegheny River. It should be noted, however, that continued pumping caused the drainage of a small pool which had been formed by damming the creek just below the well site and after two or three weeks time lowered the static level of ground water to a point 15 feet below the collar of the well. Hence the water must come from the weathered and possibly jointed rocks of the creek bed, which discharge into the well below the casing, and not necessarily from the Clarksburg limestone itself, which lies 35 feet below the surface of the ground. Furthermore, it is likely that the one-stage centrifugal pump, which draws upon the well by suction, yields much less than its rated capacity when the static level is 15 feet below the surface. Under such conditions the reported yield of the well does not demand a high water-yielding capacity for the limestone elsewhere beneath cover. The member is not known to be water-bearing where it lies 50 feet or more beneath drainage level, although at such localities it is probable that water wells would bottom in the productive Connellsville sandstone above and that the water-yielding capacity of the limestone would escape test.

The shales which accompany the Clarksburg limestone are also a source of water for domestic supplies on the flanks of the Amity anticline of northeastern Washington County, as typified by wells 354 of Peters Township and 361 of Union Township. On the western

flank of the Duquesne syncline in eastern Allegheny County the Union Collieries Coal Co. has drilled between 60 and 70 wells into these rocks for domestic supplies at its townsite of Renton. No limestone was encountered, the interval being occupied by red shale with occasional thin sandstone lentils. Most of the wells at Renton are 100 to 125 feet deep and yield from 3 to 5 gallons per minute, although the extremes are 75 to 195 feet in depth and, with the exception of one dry hole, 1½ to 17 gallons per minute in capacity. A typical example is well 299, Plum Township, at the mine superintendent's residence. In general, the deeper wells occur higher on the hillside, and in each well the source of water is a bedding plane of the shale. At the northern terminus of the axis of the Bellevernon anticline in the extreme southeastern corner of the county, these beds are reached by a very few wells in the major valleys, as well 323 in Elizabeth Township, and yield moderate water supplies. Along their outcrop at the western edge of the more closely folded terrane (Pl. I), the shales of this horizon yield small ground water supplies, typical of which are 466 of Hempfield Township and 483 of South Huntingdon Township on the eatern flank of the Port Royal syncline of Westmoreland County. Other examples are 569 and 571, Perry Township, Fayette County, on the eastern flank of the Lambert syncline.

In general, the waters from the Clarksburg limestone and associated shales are hard although they are only moderately concentrated. Analyses 299 and 569 (pp. 74, 80) are typical and represent moderately concentrated and rather hard calcium-magnesium bicarbonate waters. The relatively large content of chloride (Cl) and nitrate (NO_3) radicles in sample No. 569, is not usual for the waters of this horizon and suggests pollution by organic waste at the well site. Locally, particularly wherever the bed lies close to drainage level, the water is objectionably high in dissolved iron.

MORGANTOWN SANDSTONE

The next persistent and widely recognizable stratum below the Connellsville member is the Morgantown sandstone, for which the type locally is at Morgantown, West Virginia. The top of this sandstone is from 150 to 220 feet below the Pittsburgh coal, the interval being greatest in the western part of the region and decreasing toward the southeast. The sandstone appears, therefore, to violate the principle that all formations tend to thicken eastward. However, the member itself varies between 5 and 120 feet in thickness, and is thickest in a broad irregular zone that trends diagonally across the region from northwest to southeast. From this zone the member thins gradually towards the northeast and sharply toward the southwest, due in large part to the upper layers of the maximum section grading laterally into shale. These relations being true, the apparent reversal in direction of thickening of the beds above the Morgantown disappears.

The Morgantown sandstone is thickest in northwestern Allegheny County and along the Fayette anticline of Fayette and southern Westmoreland counties where it is the most prominent unit of the Conemaugh formation. In the Fayette anticline it is especially conspicuous and caps many of the flat-topped hills about Hunkers,

in the northeastern corner of the Connellsville quadrangle. The type phase of the Morgantown sandstone is a compact fine-grained thick-bedded rock which is micaceous and almost everywhere arkosic; its thick beds are well shown by the accompanying photograph (Fig. 27). Locally, however, the member becomes massive, coarse-grained and even pebbly, or cross-bedded; in its coarser facies it greatly re-

Figure 27.—Jointed massive and thin-bedded Morgantown sandstone, as exposed in abandoned quarry on hillside half a mile north of Dixmont, Allegheny.

sembles and has been confused with the Mahoning sandstone, which occurs some 300 feet lower in the section. As the member is traced northward along the Fayette anticline it becomes thin-bedded and flaggy, and, as it decreases in thickness, passes irregularly into interlaminated sandy shales and thin sandstone lentils.

Still farther toward the northeast, however, it is recurrent as a sandstone unit in the Latrobe syncline in the vicinity of Blairsville. To the west, on the Murrysville and Grapeville anticline (Pl. I) of the northwestern part of the county, the member is usually massive or heavy-bedded and medium-grained, although locally it grades into sandy shale.

Throughout the Kanawha section of the Appalachain plateaus southward from Butler County the Morgantown sandstone supplies many drilled wells and hillside springs along its outcrop. The type facies of the member is, however, very fine-grained and compact and contains a considerable portion of silt-size particles, so that it is not highly permeable except through small bedding plane passages. Where it is massive or heavy-bedded, however, the member has been extensively fractured during periods of crustal deformation and the joints serve as conduits for the circulation of ground water. (See Fig. 27). Locally, the coarse-grained phase is relatively permeable and yields generously to drilled wells.

Typical springs of this province are 254 of McCandless Township and 264 of Kilbuck Township, Allegheny County; 325 of Hanover Township, Beaver County; also 411 of Allegheny Township, Westmoreland County. In each of these springs the orifice occurs along a joint plane or at the intersection of a joint with a bedding plane. The phot graph (Fig. 28) shows the type of orifice at spring 264. The yield of such springs ranges between 1 and 10 gallons per minute, and varies greatly with the seasons.

Figure 28.—Orifice of spring No. 264, showing ground water conduit at intersection of vertical joint and bedding plane in dense facies of the Morgantown sandstone.

The water-yielding capacity of the Morgantown sandstone in Allegheny County is represented by wells 232 of Pine Township, 255 of McCandles Township, 265 of Ross Township, 280 of Stowe Township, 284 and 285 of Findley Township, 291 of Penn Township, 1026 of Plum Township, 302 and 303 of Patton Township, 304 of North Fayette Township, 316 of Clairton Borough, 317 of Jefferson Township, and 324 of Hanover Township. In Washington County a shaly facies of the member is tapped by wells 334 of Smith Township, and 358 of Union Township. Well 358, however, has an ultimate capacity of about 65 gallons per minute, a rate of yield which requires a permeability far greater than any possessed by shale. It seems likely, therefore, that the texture of the water-bearing stratum approaches that of the typical sandstone. Farther south, in the Monongahela Valley, the member is reached by wells 378 of Speers Borough and 398 of West Pike Run Township, Washington County, also by 581 of Jefferson Township and 594 of South Brownsville Borough, Fayette County. In the western part of Westmoreland County the member is reached by wells 420 of Franklin Township, 425 of Export Borough, and 453 of Sewickley Township. Where the member lies above drainage level or is very compact, the yield to wells is seldom more than 1 or 2 gallons per minute; a few wells proved to be inadequate for domestic use. Where the member lies below drainage level, on the

other hand, it retains water under moderate hydrostatic head and, if coarse-grained, yields copiously to wells. Such conditions are fulfilled at four localities: first, in the vicinity of Imperial, in western Allegheny County, where well 304 and others yield 75 gallons per minute or less; second, in northeastern Washington County at well 358, whose ultimate capacity is about 65 gallons per minute; third, at Export, in northwestern Westmoreland County, at well 425; and last, in the vicinity of New Madison, in southwestern Westmorleand County, where well 453 is reported to yield 35 gallons per minute. With these exceptions, none of the wells have been pumped more than 5 gallons per minute, so that the ultimate water yielding capacity of the member is unknown. So far as is known wells flowing by artesian pressure are not obtainable from the Morgantown sandstone at any point in the Kanawha section.

In central Greene County the Morgantown sandstone is beneath deep cover but is found to be water-bearing in many deep wells, as in No. 1077 of Morgan Township, 1079 of Center Township, and 1098 of Gilmore Township. Usually, the yield is not more than one or two gallons per minute and the water is much too highly mineralized to be potable.

In the more closely folded rocks of the Allegheny Mountain district, the Morgantown sandstone is even more conspicuous as a source of ground water. Representative wells in Westmoreland County are No. 434 of Salem Township, No. 439 contiguous to Derry Township, 444 and 446 of Fairfield Township, 456 of Sewickley Township, 461 of Hempfield Township, 487 of South Huntingdon Township, 489 of Scottdale Borough, also 492, 495, and 500 of Mount Pleasant Township. The member is also tapped by well 549 of Monongahela Township, southeastern Greene County. Typical wells in Fayette County are No. 570 of Perry Township, 572 of Dawson Borough, 584 of Franklin Township, 600 of Menallen Township, 610 of German Township, and 617 of Georges Township. Most of these wells have not been pumped more thon 10 to 15 gallons per minute so that the ultimate water-yielding capacity of the member is not known. At site 446 however, well No. 1 of the Westmoreland-Connellsville Coal & Coke Co., at Fort Palmer, has yielded about 50 gallons per minute since 1909 with only occasional shutdowns. This well is 311 feet deep. However, it is reported that well No. 2, which is 200 feet northwest of well No. 1 and 335 feet deep could be exhausted by pumping 40 gallons per minute for about 3 hours, but that it recovered in 24 hours or less. Well No. 3, approximately 350 yards east of No. 1 and 414 feet deep, yielded less than 5 gallons per minute. Wells 2 and 3 have been abandonded. This experience indicates wide variations in permeability even in a small area, which is compatible with known abrupt lateral changes in grain-size where the member has been studied at the outcrop. Well 489, of the Scottdale Ice & Coal Co., is pumped steadily at the rate of 50 gallons a minute for as much as three months of the summer and is reported to have been tested at the rate of 140 gallons a minute for a period of 8 hours. Hence the specific capacity is about 3 gallons per minute for each foot of draw-down, a permeability which is relatively large for a consolidated sandstone.

That an artesian condition exists in the Morgantown sandstone in

the Allegheny Mountain district is attested by well 617 of Georges Township, Fayette County, and which was flowing at the estimated rate of 200 gallons per minute during October, 1926. The head is not great, however, and the area of artesian flow is probably limited to the beds of George Creek, Muddy Run, and possibly also of Yorks Run in the region near Fairchance and Smithfield. Although other flowing wells are unknown, it is possible that similar artesian areas exist along the axis and eastern flank of the Uniontown syncline (Pl. I) wherever the streams have cut below the 1150 foot contour.

The shaly facies of the Morgantown member is usually a source of water supplies of household magnitude in this same district, typical examples being wells 435 of New Alexandria Borough, Westmoreland County; also 575 and 577 of Bullskin Township, Fayette County.

The chemical character of the water from the Morgantown sandstone is shown by analyses 280, 302, 304, 325, 489, 570, and 617 (pp. 74-81), as well as by the accompanying diagram (Fig. 29). Analysis 577 represents the water from the shaly facies of the member.

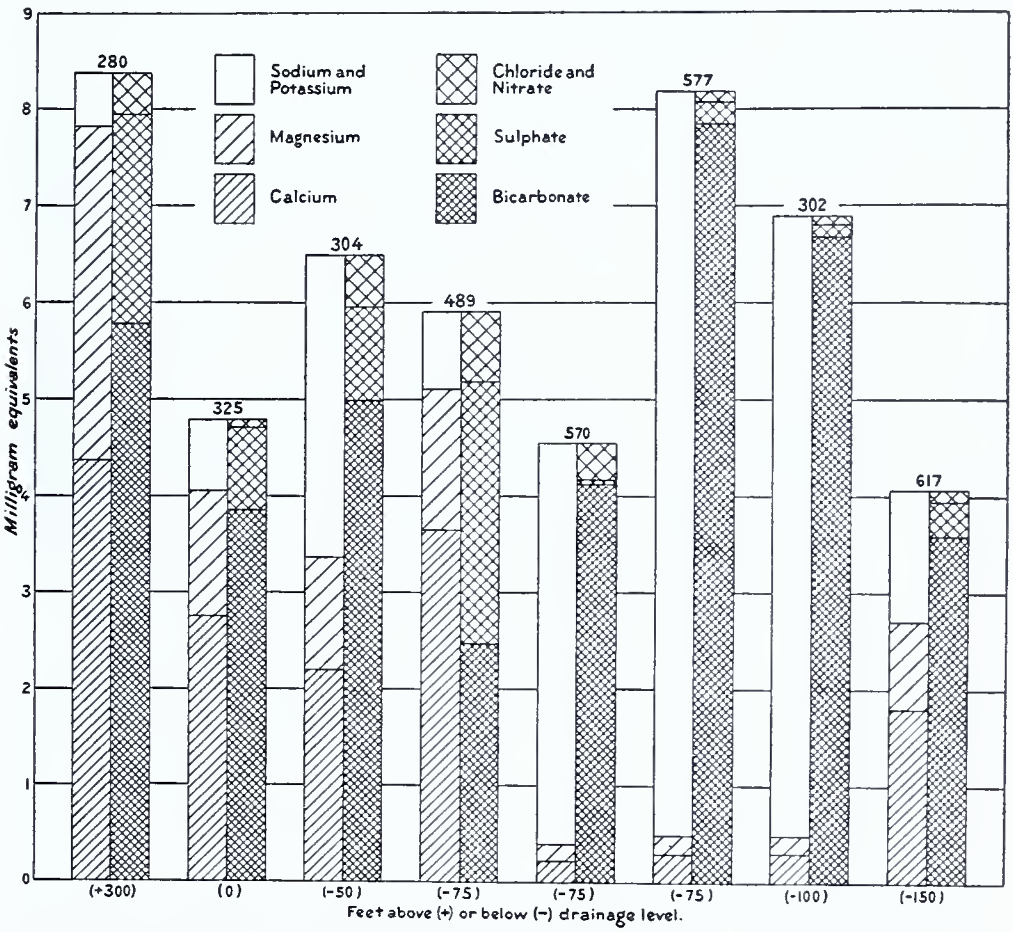


Figure 29.—Relation between quality of waters from the Morgantown sandstone and distance of that stratum above or below nearby surface streams.

Where the member lies above drainage level in the district west of Chestnut Ridge or not more than 100 feet below drainage level in the Allegheny Mountain district, as in wells 280, 325, and 489, it con-

tains a moderately concentrated hard water that is a scale-former and soap-consumer. Where the member lies at greater depth, however, as in well 570, it contains very soft sodium bicarbonate water that is satisfactory for all domestic uses but is likely to foam if used in boilers without preliminary treatment (see pp. 85-87). The water of the Morgantown sandstone is usually almost free of dissolved iron, but analysis 489 represents a water that contains so much iron that it is unfit for many purposes. In the well from which this sample was taken, however, the overlying shales of the Clarksburg limestone horizon, which are known to yield iron-bearing water at some places, are not cased off. Hence, it is possible that much of the dissolved iron (Fe) is derived from the shales and not from the Morgantown sandstone. Well 378 of Speers Borough, southeastern Washington County, also encountered iron-bearing or "red" water 60 feet below the surface in the top of the Morgantown sandstone and at the base of an overburden of sand and other unconsolidated river deposits. After this inferior water had been shut off by casing to a depth of 70 feet, iron-free water was encountered in a porous zone of the sandstone from 70 to 73 feet below the surface. Adequate casing of wells which reach the Morgantown sandstone is indicated as a possible means of precluding an undesirably large content of dissolved iron in the water developed. Furthermore, where the member lies 100 feet or more below regional drainage level, as on the flanks of the Brownsville anticline of western Fayette County and farther to the west, highly concentrated brines may be encountered. Such was the experience of wells 581 of Jefferson Township and 594 of South Brownsville Borough.

BIRMINGHAM SHALE

The Birmingham shale, originally described by Stevenson,[1] grades irregularly and sometimes abruptly into sandy shales interbedded locally with massive sandstone lentils, and, in part at least, is equivalent to the lower portion of the Morgantown sandstone where that member is thickest. The extreme variation in lithology has made it impossible to recognize this member over a wide area, so that the name is of local significance only.

In general the Birmingham shale is not highly permeable to ground water, although it yields household supplies in the vicinity of its outcrops in northern and western Allegheny County. Wells 271 of O'Hara Township, 233 of Pine Township, 253 of McCandless Township, 266 of Ross Township, and 305 of North Fayette Township are representative. In the greater part of this area successful wells can usually be obtained in the shale, although the yield is usually not more than one or two gallons per minute and adjacent wells may obtain water at very different levels. Farther south, in the Monongahela Valley of eastern Greene County, beds of shale at the horizon of the Birmingham member are water-bearing in well 547 of Greensboro Borough. Well 621 of Georges Township, Fayette County, on the east flank of the Uniontown syncline, also finds water in beds of shale at this horizon.

[1] Stevenson, J. J., Pa. Second Geol. Survey Rept. K, p. 79.

DUQUESNE (BERLIN) COAL

The base of the Birmingham shale is marked in the type region by a variable and discontinuous bed of coal which is not more than 4 feet thick. It is rather persistent in Allegheny County.

The Duquesne coal is underlain by sandy yellow shales and local bright red clayey shale ("Washington Reds") which extend down to the Ames limestone.

The Duquesne coal is not usually a source of ground water, although a sandy carbonaceous shale which occupies its approximate horizon is the source rock of wells 424 in Export Borough, and 459 of Hempfield Township, Westmoreland County. Farther east, on the western flank of the Chestnut Ridge anticline, the outcrop of this same horizon is locally the site of small hillside springs, of which 441 of Derry Township, is typical. In this district of high relief, however, such springs do not indicate high permeability for the member beneath cover.

The water from the shales at the horizon of the Duquesne coal is shown by analysis 424 (p. 77) to be moderately concentrated but very soft where the water-bearing bed lies far below drainage level. This water has presumably been softened by exchange of bases with rock-forming minerals. It has very little soap-consuming power but it is likely to foam in a troublesome manner if used in boilers without preliminary treatment.

AMES LIMESTONE

The uppermost persistent limestone of the Conemaugh formation is the Ames limestone, named from the type region in Ames Township, Athens County, Ohio. It lies from 230 to 350 feet below the Pittsburgh coal, the interval increasing eastward, and about 20 feet below the Duquesne coal. In the average section it is 275 feet below the base of the Pittsburgh coal and 350 feet above the top of the Upper Freeport coal. The Ames limestone ranges from a mere seam to a stratum 8 feet thick, although at most places east of the Allegheny and Monongahela rivers, it is less than 3 feet thick.

The outcrop of the Ames limestone is the site of scattered hillside springs, most of which probably originate in soil water which percolates downward through the overlying distintegrated shales and is trapped above the resistant limestone. Where the member lies beneath cover, solution channels have not been formed along bedding or joint planes, as they have in the non-marine limestones of the overlying strata, and hence is not usually a source of water. On syncline flanks and in the vicinity of the outcrop, bodies of ground water occur locally at the base of the member, as in well 234 of Richland Township, Allegheny County but commonly, however, the Ames limestone is not a source of ground water.

"PITTSBURGH REDS"

The interval between the Ames limestone member and the underlying Saltsburg sandstone is occupied by greenish-gray, red, and variegated shales. In many parts of the region, especially in the west and north, the red strata become of sufficient thickness to be re-

garded as an individual unit, generally known as the "Pittsburgh Reds." The top of this division is marked by a persistent brilliant red clayey shale which lies 10 to 25 feet below the Ames limestone and ranges between 5 and 15 feet in thickness. In many places this stratum serves to discriminate the overlying Ames from other limestone members with which it may be confused. This characteristic upper stratum is succeeded by interlaminated and interfingered red and gray shales which make up a group from 0 to 75 feet thick.

The strata of the "Pittsburgh Red" horizon are usually not permeable to ground water beneath cover, although above drainage level they yield many small supplies to drilled wells not more than 150 feet deep in northern and western Allegheny County. Typical wells are 230 of Pine Township, 237 of Richland Township, 267 of Ross Township, 270 of Shaler Township, and 282 near the boundary of Findley Township. The yield of most of these wells is not more than one gallon per minute and the head is small. Usually the ground water occurs in minute bedding plane channels which are not persistent at a given horizon so that adjacent wells may differ greatly in depth to the water-bearing stratum and in capacity. Wells 409 of Allegheny Township and 419 of Washington Township, northern Westmoreland County, also derive their supplies at the horizon of the "Pittsburgh Reds." Farther south, in the Monongahela Valley, a sandy facies of these shales was formerly tapped by well 318, Jefferson Township, Allegheny County, as well as by 627 of Point Marion Borough, Fayette County. Where the rocks are more closely folded these beds also yield sparse water supplies of small magnitude, as in well 468 of Unity Township, Westmoreland County.

SALTSBURG SANDSTONE

On Kiskiminetas River in the vicinity of Saltsburg, the section comprises an upper sandstone 100 feet thick, a bed of shale 10 feet thick, a median stratum of sandstone 50 feet thick, variegated shale 20 feet thick, and a lower sandstone 15 feet thick. The top of the section is 262 feet above the Upper Freeport coal.

In general the Saltsburg sandstone lies between 300 and 500 feet below the Pittsburgh coal and from 170 to 285 feet above the Upper Freeport coal, both intervals increasing eastward although subject to considerable local irregularities. In the average section it is about 375 feet below the Pittsburgh coal and 80 feet below the Ames limestone. The member has been described as ranging from 20 to about 85 feet in thickness, although the thicker sections may include the Buffalo sandstone at the base. The rock is typically heavy-bedded or massive, fine-grained, and white, gray, or yellowish. Within short distances it may grade into a very thin-bedded argilaceous sandstone or a bluish-gray sandy shale or, less frequently, into a coarse-grained or even pebbly irregularly-bedded rock. The Saltsburg and Buffalo sandstone members are most prominent in Westmoreland County, within which they form extensive table lands along Youghiogheny River.

The Saltsburg member is also moderately persistent in Allegheny County and southern Butler County, but is not everywhere present in Fayette County.

The typical heavy-bedded facies of the Saltsburg is very widely known to the well driller as the Little Dunkard sand.

The Saltsburg sandstone is a prominent though erratic water-bearer in Allegheny County and small contiguous portions of southern Butler County, of extreme northwestern Washington County, and of westernmost Westmoreland County. In this district the outcrop of the member is the site of many permanent though variable hillside springs where the flanks or plunging axes of folds are exposed by stream valleys. Typical wells are 198 of Jefferson Township and 214 of Mars Borough of Butler County; also 275 of Springdale Borough, Allegheny County. Few of these springs exceed 10 gallons per minute in yield.

The water-yielding capacity is shown further by wells 192 of Penn Township and 218 of Middlesex Township, in southern Butler County; also in Allegheny County by 226 of Marshall Township, 229 and 231 of Pine Township, 236 and 238 of Richland Township, 246 of West Deer Township, 258 of Hampton Township, 262 of Indiana Township, 286 of Findley Township, 290 of Penn Township, 298 of Plum Township, 308 and 309 of North Fayette Township, 1028 of Scott Township, 312 of Versailles Township, 1037 of Snowden Township. Others in the same district are wells 326 of Hanover Township and 330 of Robinson Township, Washington County; also 427 of Penn Township, and 447 of North Huntingdon Township, in westernmost Westmoreland County. Most of these wells encounter water in the intergranular spaces of coarse-grained or pebbly beds, which are most abundant below the Bakerstown coal or its horizon. These coarse-grained beds are relatively very permeable and even when above drainage level yield water copiously where the geologic structure is favorable. Where they lie below drainage level they retain water under moderate hydrostatic head in the synclines and along the axes of the plunging anticlines (Pl. I), and drilled wells which penetrate them have specific capacities of the order of 10 gallons per minute for each foot of drawdown. However, these coarse-grained beds seem to be irregular lenses or pipes enclosed by finer material which is much less permeable, so that adjacent wells may have very different capacities. Under such circumstances the development of large supplies is more or less a matter of chance. Several typical examples are described in the following paragraph. Locally the sandstones have been extensively fractured during crustal deformation and fracture planes form conduits for ground water circulation.

The few representative wells which have been tested to capacity include Nos. 238 and 258, in the western flank and crest, respectively, of the Kellersburg anticline (Pl. I) of north-central Allegheny County. These two wells, which find the water-bearing beds approximately at drainage level, have respective ultimate capacities of 3½ and 5 gallons per minute. Of wells which encounter these sandstones below drainage level, No. 231 flowed by artesian pressure at the rate of 3 gallons per minute and yielded about 40 gallons a minute with a reported drawdown of 4 feet during an 18-hour pumping test in September, 1926. Well 230, however, located to the west and slightly higher on the southward-plunging syncline (Pl. I and Fig. 35), attained the same stratigraphic horizon but did not encounter water in the sandstones. Well 290 yielded 108 gallons per minute during a 24-hour test, the report seemingly having adequate authority, although the

drawdown is not known. Well 291, on the other hand, about half a mile to the southwest, reached a point 60 feet stratigraphically below the bottom of well 290 and found that the sandstone was not water-bearing. No. 312 embraces a group of five wells, of which two are reported to have discharged 114 gallons per minute each with a draw-down of 8 feet when tested separately at the time of drilling in 1925.

This indicates a specific capacity of 14 gallons per minute for each foot of drawdown. The three other wells yielded somewhat less copiously. Serious interference results if all five wells are pumped simultaneously, although three are usually pumped at one time without interference. At site 326, at the old Frankfort compressing station, a gang of six wells supplied water for the condensers, the reported aggregate yield being 650 gallons per minute. This reported yield seems to be of the proper order of magnitude. During the summer of 1926 this compressing station was being rebuilt and the wells rehabilitated. At site 330, two wells about 100 feet apart have been pumped at the aggregate rate of 100 to 120 gallons per minute for periods as much as three months in duration. Two other wells drilled about 300 feet upstream and 500 feet downstream, respectively, from this site penetrated the Saltsburg sandstone but obtained only a small yield. Furthermore, wells 1044 of Hanover Township and 1045 of Robinson Township passed entirely through the Saltsburg sandstone without finding water. South and west of Pittsburgh few wells reach the member, inasmuch as the overlying Morgantown sandstone is almost everywhere water-bearing and adequate supplies are usually obtainable from that member. At the Sturgeon naphtha plant of the South Penn Oil Co., a mile east of McDonald, however, wells 308 and 309 draw a portion of their supply from the Saltsburg sandstone. Well 308, completed October 7, 1926, yielded from three water-bearing strata about 40 gallons per minute by air lift pump with a drawdown of 60 feet, as indicated by differential air pressures. On November 3, 1926, the well having been pumped steadily in the meantime, the yield was 25 or 30 gallons per minute and the water level, while pumping, was 175 feet below the original static level. The decreased yield was perhaps due in large part to the lessened efficiency of the air lift as its ratio of submergence decreased as the static level in the well declined, and not primarily to depletion of the supply. However, it is clear that the original draft of 40 gallons per minute exceeds the rate of inflow. The yield of well 309 is of comparable magnitude.

In addition to well 231, to which reference has been made above, No. 218 of south-central Butler County also flows by artesian pressure, the rate of yield being about 3 gallons per minute. Furthermore, it is reported though not confirmed, that well 290 in northeastern Allegheny County flowed slightly by artesian pressure when first drilled. These three wells are located on gently folded southward-plunging strata (Pl. I). In each case the head is less than 10 feet above the surface, and the area of potential artesian flow is small, being limited to the creek bed below the contour of the well site and within the given structural unit.

Locally within this district, a shaly facies of the Saltsburg sandstone yields water from small bedding plane passages, usually at the upper or lower surface of a sandstone lentil. Representative wells are 178 of Summit Township and 210 of Cranberry Township of southern

Butler County; also 227 of Marshall Township and 272 of O'Hara Township, Allegheny County.

Southward from Allegheny County the Saltsburg and Buffalo sandstones pass beneath deep cover and lie for the most part below regional drainage level. Consequently, little is known of their water-yielding capacity except that they are not usually water-bearing in deep oil and gas wells. Typical deep wells which found these sandstones to be water-bearing are No. 1021 of Findley Township, and 1028 of Scott Township, and 1037 of Snowden Township, Allegheny County; No. 1044 of Hanover Township, 1049 of Jefferson Township, and 1053 of Peters Township, Washington County; No. 1082 of Jefferson Township, 1090 of Whiteley Township, 1095 of Wayne Township, also 1097 and 1098 of Perry Township, Greene County.

In the more closely folded rocks which lie east of the Lambert-Port Royal syncline (Pl. I) the Saltsburg sandstone is also a conspicuous source of ground water, especially in Westmoreland County. On the east flank of the Port Royal syncline it is water-bearing in some deep wells, as in No. 1069 of Hempfield Township, Westmoreland County, although the shallow water-supply wells do not reach it. On the flanks of the Greensburg syncline the sandstone supplies many wells of household magnitude where it lies above drainage level, as in wells 458 and 464 of Hempfield Township. Locally it displays a shaly facies, as in well 464. In the region of its maximum thickness along the crest of the Fayette anticline the Saltsburg member is tapped by many wells on the hilltops about Hunkers, such as well 484 of South Huntingdon Township, Westmoreland County. Far to the south the member passes below drainage level on the plunging axis of this fold and in Point Marion Borough of Fayette County is entered by well 628, which has a specific capacity of about 5 gallons a minute for each foot of drawdown. Hence the member has moderate permeability at that locality. In much of the intervening terrane, however, it is shaly and not an important source rock, well 599 of Menallen Township, for example, passing entirely through without finding water.

The typical heavy-bedded permeable facies of the Saltsburg sandstone is quite generally present in the Latrobe-Uniontown syncline (Pl. I) and is an outstanding water-bearer. Many drilled wells reach the member under moderately thick cover along the flanks of the fold and small hillside springs are numerous at its outcrop.

Representative wells in Westmoreland County are Nos. 496 and 497 of Mount Pleasant Township. For the southern portion of the syncline, in Fayette County, wells 589 and 1102 of Connellsville Township, 611 of South Union Township, and 618 of Fairchance Borough are typical. Where this heavy-bedded facies lies below drainage level the specific capacities of drilled wells range from 0.3 to 7.5 gallons per minute for each foot of drawdown. Locally, however, the member passes into interlaminated shales and sandstone lentils and yields less abundantly, as in wells 469 of Unity Township, Westmoreland County, 587 of Dunbar Borough and 620 of Georges Township, Fayette County. Throughout this synclinal trough the member retains water under moderate head and supplies several flowing wells at low points of the topographic surface where the geologic structure is favorable. Among the representative wells are Nos. 469, 496, and 497. At each of these wells the artesian head is small and the potential flow not more than a

few tens of gallons a minute. It is not possible from the few data available to outline the artesian area with any precision, but flowing wells may be expected from the coarse-grained facies of the Saltsburg sandstone in the axial portion of the trough wherever the streams have cut below the 1200-foot contour in the region southward from Latrobe as far as the Westmoreland County boundary. However, the hydraulic gradient is rather steep toward the axis of the trough from either flank, so that potential rates of flow at various localities remain of the same order of magnitude as for the few existing wells. Farther south, in Fayette County, the piezometric surface passes beneath the deepest valleys so that flowing wells are not obtainable from the Saltsburg sandstone.

In the Ligonier syncline, to the east, the Saltsburg sandstone lies for the most part above drainage level except in the northernmost part of the trough in Westmoreland County. Hence the member is not an outstanding water-bearer, although its outcrop is the locus of many hillside springs and it serves some drilled wells of domestic size, such as well 506 of Donegal Township. The member is also water-bearing in well 445 of Fairfield Township, although not the principal water-bearing bed.

The chemical character of the water from the Saltsburg sandstone is discussed with that of the underlying Buffalo sandstone member in a subsequent paragraph (p. 176).

UPPER AND LOWER BAKERSTOWN COALS AND ASSOCIATED ROCKS

In central Allegheny County and adjacent areas, the Saltsburg sandstone is underlain at many places by a group of gray and red sandy shales that enclose one or two beds of coal and two discontinuous beds of limestone. In some parts of the area, particularly in Westmoreland County, some or all of these beds are absent and their horizon is filled by a thick facies of the Saltsburg sandstone.

The Upper Bakerstown coal lies close below the Saltsburg sandstone. Generally, it is only a few inches thick. The Woods Run limestone, 1 to 2 feet thick, is about 6 feet below the Upper Bakerstown coal. The Lower Bakerstown coal ranges in thickness from 0 to 7 feet and is from 4 to 20 feet below the Woods Run limestone. In the Ligonier Valley of southwestern Fayette County, the Hager and Farmington coals occur at the approximate horizon of the Bakerstown coals but there is no sound basis for considering them as contemporaneous.

The Lower Bakerstown coal or the sandy shale which lies immediately above it is a persistent source of ground water in northern Allegheny County, although most wells do not tap it because of the inferior quality of the water. Over most of the region the coal is absent or is represented only by a fine-grained carbonaceous shale. This rock is not permeable to ground water and acts as a barrier to downward percolation. Hence, along the flanks of folds and in the vicinity of the outcrop, bodies of ground water may be upheld above drainage level by the coal. Representative wells are No. 203 of Winfield Township, Butler County, and 503 of Cook Township, southeastern Westmoreland County. In general, however, such bodies of ground water are few and scattered, the water is confined under small head, and the yield is small. In the extreme northwestern portion of

Westmoreland County the horizon of the Bakerstown coal seems to be occupied by a sandy black shale which is moderately permeable and locally yields moderate supplies where it lies at or below drainage level. Typical wells are No. 417 of Upper Burrell Township and 418 of Washington Township. Farther east, on the west flank of the Fayette anticline (Pl. I), the horizon is also occupied by sandy shales which are locally water-bearing as in well 437 of Derry Township.

The chemical character of the water from the more carbonaceous facies of the Bakerstown coal horizon is shown by analysis 503 (p. 79). This water is only slightly concentrated, and its hardness is only 67 parts per million. However, it contains sufficient iron to render it undesirable for any ordinary use.

Below the Lower Bakerstown coal, where that bed is recognizable, and at the corresponding horizon elsewhere, there occurs in most localities a group of gray, brownish-yellow, or red shales and thin sandstones. Locally, however, these beds are replaced, in whole or in part, by a single sandstone lentil as much as 40 feet thick.

This group of shales is not highly permeable, although minute bedding plane channels in it supply many household wells, especially above drainage level on the flanks of folds. Where they lie more than 75 feet below the surface they are not commonly water-bearing. Representative wells which tap these shales in Butler County are No. 177 of Summit Township; 209 of Cranberry Township; of Allegheny County, No. 239 of West Deer Township; 250 of Harrison Township; 256 and 259 of Hampton Township; 261 of Indiana Township; 268 of Ross Township; and 289 of Penn Township. Others are 438 of Derry Township and 462 of Hempfield Township, Westmoreland County; also 629 of Springhill Township, Fayette County. Most of these wells yield about one gallon per minute. Although only a few wells are unsuccessful, the depth at which water is found within these beds is largely a matter of chance and adjacent wells may differ greatly in depth and capacity. Where the limestone members of the horizon are present, bedding plane channels at their lower or upper surfaces are locally sources of small supplies. Representative wells are Nos. 228 of Marshall Township and 274 of Springdale Township, both of Allegheny County.

The water from the Bakerstown coals and associated rocks is shown by analyses 177, 228, and 438, (pp. 73, 77), to be only moderately concentrated. Nos. 177 and 438 represent moderately hard waters from above drainage level; 228 represents a partly softened water from a well that reaches the water-bearing member about 50 feet below drainage level. The waters from this group of beds are nearly free from iron.

BUFFALO SANDSTONE

The type region of the Buffalo sandstone[70] is in the basin of Buffalo Creek, in the southeastern corner of Butler County. In this region its top is 450 to 510 feet below the Pittsburgh coal, its maximum thickness is 60 feet, and the rock is a coarse-grained or conglomeratic sandstone made up of quartz grains and pebbles which are usually not more than half an inch in diameter. This type phase persists across the southern part of Butler County. Farther south and west, however,

[70] White, I. C., Pa. Second Geol. Survey Rept. Q, pp. 33-34.

in the western half of Allegheny County, the member thins to 20 feet or less and grades laterally into variable massive or thin-bedded fine-grained greenish gray sandstone or into reddish sandy shale. It is massive or cross-bedded and fine to medium-grained in the northwestern corner of Westmoreland County.

The Buffalo sandstone, like the overlying Saltsburg member, is a conspicuous water-bearer wherever its coarse-grained permeable phase lies below drainage level, although its water-yielding capacity varies widely. Typical wells in southern Butler County, the type region, are No. 161 of Connoquenessing Township, 193 of Jefferson Township, 201 of Winfield Township, 215 of Valencia Borough, and 217 of Middlesex Township. In this same district, however, well 194 of Jefferson Township penetrates the member without finding water. In Richland Township of north-central Allegheny County, five wells ranging in depth from 155 to 315 feet reach this member at site 235. Farther south the sandstone grades into shale which is almost impermeable, as in well 281 of Allegheny Borough. In the southeastern part of the county, however, the horizon is again filled with sandstone which is tapped by well 313 of Versailles Township. Well 421 of Franklin Township, Westmoreland County is similar. The Buffalo sandstone is probably most productive in the closely folded terrane of northeastern Westmoreland County, as typified by wells 431 of Salem Township in the axial portion of the Elders Ridge syncline (Pl. I) and 443 of Latrobe Borough on the axis of the Latrobe syncline. Where the member lies above drainage level on the flanks of the folds, as in well 470 of Unity Township, its water-yielding capacity is small. Farther south, in Fayette County, wells 599 of Menallen Township, and 639 of Henry Clay Township are representative.

Southward and westward from Allegheny County the horizon of the Buffalo sandstone passes beneath deep cover and is known only from the records of deep wells. At site 1054, in Peters Township of northeastern Washington County, the member was found to be water-bearing 620 feet below the surface, although this condition is not usual.

The chemical character of the waters from the Saltsburg and Buffalo sandstones is shown by analyses 192, 226, 231, 236, 326, 431, 496, 497, 589, and 628 (see pp. 73-81, and fig. 30). Most of the waters from these sandstones in the area west of Chestnut Ridge are moderately concentrated, whereas many of those from the closely folded rocks of the Allegheny Mountain district are usually only slightly concentrated. Nos. 192 and 231 are moderately hard waters from above drainage level; No. 431, on the other hand, represents a completely softened water from a well that reaches the sandstones 200 feet below drainage level. The Saltsburg and Buffalo sandstones seem to be somewhat deficient in minerals that have the property of base exchange, so that their water may be somewhat harder than the water in the overlying Morgantown sandstone at a given depth below drainage level. Some of the waters from the Saltsburg sandstone contain so much dissolved iron that they are likely to stain linens and receptacles and to deposit an iron-oxide sludge in pipes and storage tanks. The iron-rich waters seem to have no definite range geographically or in depth of the water-bearing bed below the surface, nor to bear any relation to the total of dissolved solids. Rather, their range is to some extent strati-

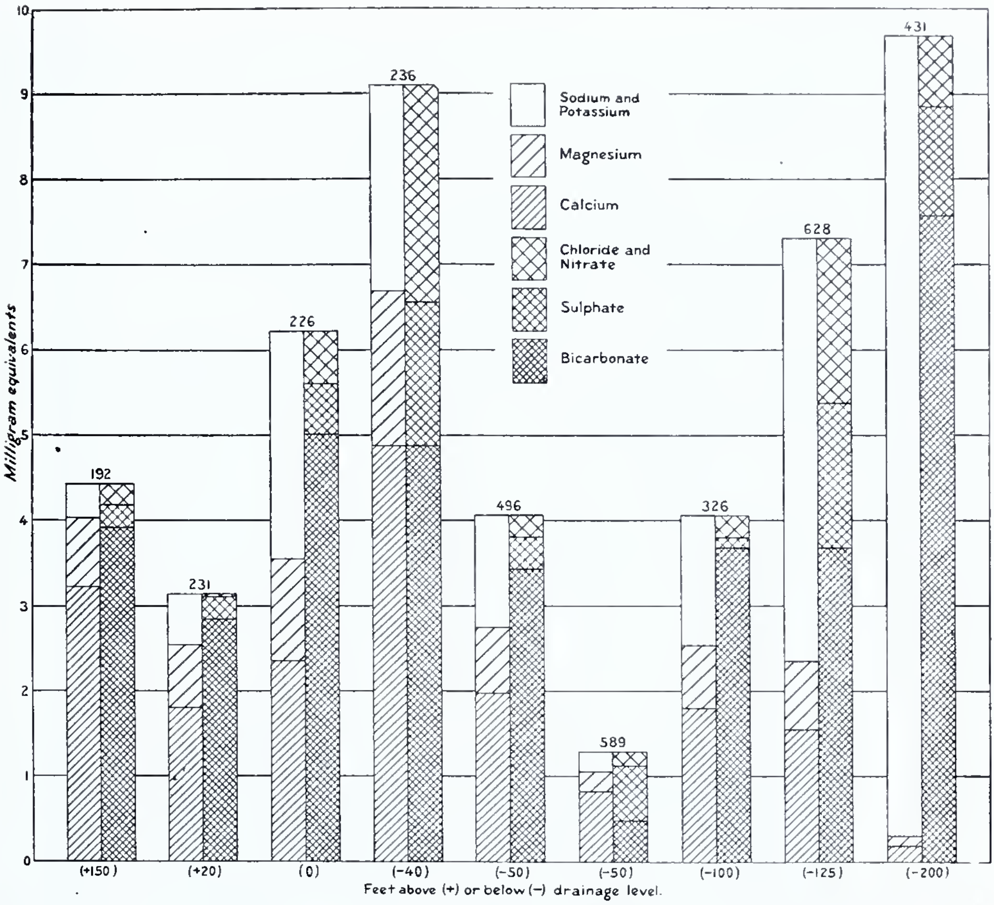


Figure 30. Relation of the quality of waters from the Saltsburg and Buffalo sandstones to the distance of the water-bearing stratum above or below nearby surface streams.

graphic, in that they occur more frequently at the approximate horizon of the Bakerstown coal, even though that bed may not be recognizable.

Analyses 227, 308, and 309 (pp. 73, 75) represent brackish water from the Saltsburg and Buffalo sandstones that is unsuitable for domestic consumption or for industrial uses other than the cooling of condensers. These sandstones also contain salty water in well No. 286 of Findley Township, Allegheny County. In the Latrobe syncline of central Westmoreland County, they contain brine that was formerly pumped from wells at Latrobe as a source of common salt. The origin of these salty waters has been discussed on pages 88-91.

BRUSH CREEK COAL AND ASSOCIATED ROCKS

Immediately below the Buffalo sandstone, or separated from it by a few feet of light-brown shale, is the Cambridge limestone, which has also been called Upper Cambridge limestone and Brush Creek limestone. This member is a very compact limestone 1 or 2 feet thick but in places its horizon is occupied by a black calcareous shale 4 to 5 feet thick. Locally the bed is highly ferruginous. The Cambridge limestone is underlain by 10 to 17 feet of light-brown to dark carbonaceous shale, which separates it from the Brush Creek coal.

In its type region, the western part of Allegheny County, the Brush Creek coal lies between 140 and 200 feet below the Ames limestone and from 70 to 120 feet above the Upper Freeport coal, the average intervals increasing southeastward. At some places the member consists of clean coal that ranges in thickness between 2 inches and 5 feet, but generally its horizon is occupied by dark carbonaceous shale that may be accompanied by a thin dark-blue limestone.

The Brush Creek coal is underlain by a discontinuous thin bed of clay and that in turn by thinly laminated shales about 20 feet thick which extend to the top of the Mahoning sandstone.

The variable beds which constitute this interval between the Buffalo sandstone above and the Mahoning sandstone below, supply a few hillside springs and many drilled wells of household size in the district between Pittsburgh and Butler. In the western part of this district especially, the underlying Mahoning sandstone is shaly over extensive areas and not water-bearing beneath deep cover, so that the horizon of the Brush Creek coal is the only source of water supplies. Typical wells and springs in Butler County are No. 165 of Butler Township, 190 and 191 of Penn Township, 196 of Jefferson Township, 200 of Winfield Township, 211 of Adams Township, and 220 of Clinton Township. For Allegheny County, representative wells are Nos. 245 and 1013 of West Deer Township, 269 of Ross Township, 276 of Springdale Township, 277 near Hopewell Township, and 296 of Plum Township. In the eastern part of the district wells 414 and 416 of Lower Burrell Township, Westmoreland County, are typical. Most of the beds at this horizon yield water only along the flanks of folds and above drainage level, circulation being by means of minute bedding plane channels in the vicinity of the outcrop. Many of the wells encounter perched water 50 feet or less beneath the surface and yield only 1 or 2 gallons per minute. In such wells the hydrostatic head is low and it is generally necessary to drill below the water-bearing bed to provide storage within the well. In some places the beds of this horizon are sandy or are jointed and are water-bearing beneath 100 feet or more of cover. Typical wells are Nos. 191, 245, and 276. Where they are water-bearing at depth, and the overlying Buffalo sandstone contains iron-bearing water these beds are a valuable source of water, as in well 191. Wells which tap the more permeable phases of these beds where they are below drainage level and are saturated have capacities of 15 to 25 gallons per minute, as Nos. 200 and 276. Most wells which enter these beds where they are above drainage level have a capacity less than 5 gallons per minute.

The water from the beds of the Brush Creek coal horizon is slightly to moderately concentrated and is satisfactory for most domestic and industrial uses. Where the beds are above drainage level the water is moderately hard, but where they lie far below drainage level the water is relatively soft. Many of the waters contain enough iron to be unsatisfactory for many uses, particularly where the beds lie comparatively near the surface and have been oxidized. Analysis 191 (p. 73) is representative.

MAHONING SANDSTONE

The Mahoning sandstone lies between the Brush Creek coal above and the Upper Freeport coal below. As thus defined its top is 420

to 600 feet below the Pittsburgh coal, approximately 200 to 250 feet below the Ames limestone, and 100 feet above the Upper Freeport coal. The trace of the outcrop of the base of this member may be followed on the geologic map (Pl. I) as the boundary between the Conemaugh and Allegheny formations. The Mahoning sandstone is thickest in the western part of the area covered by this report, where it is almost always a triple member comprising two sandstone beds each 10 to 80 feet thick and a median group of shale, thin coal, limestone, and clay. The uppermost and lowermost beds generally thicken inversely to one another and the entire member has a thickness of 20 to 100 feet. Farther east, however, in Fayette and Westmoreland counties, the member becomes even more variable in lithology, is from 10 to 60 feet thick, and is less conspicuous than either the Morgantown or the Saltsburg sandstone. The typical Mahoning sandstone is light-gray to yellowish-brown and massive or heavy-bedded, and is medium or coarse-grained. Either or both of its two divisions may be massive and conglomeratic on the one hand, or on the other, may pass into sandy drab shales by lateral gradation or abrupt change.

The lithologic character of the beds in this district is well shown by the photographs (Figs. 31 and 32). In extreme cases the strati-

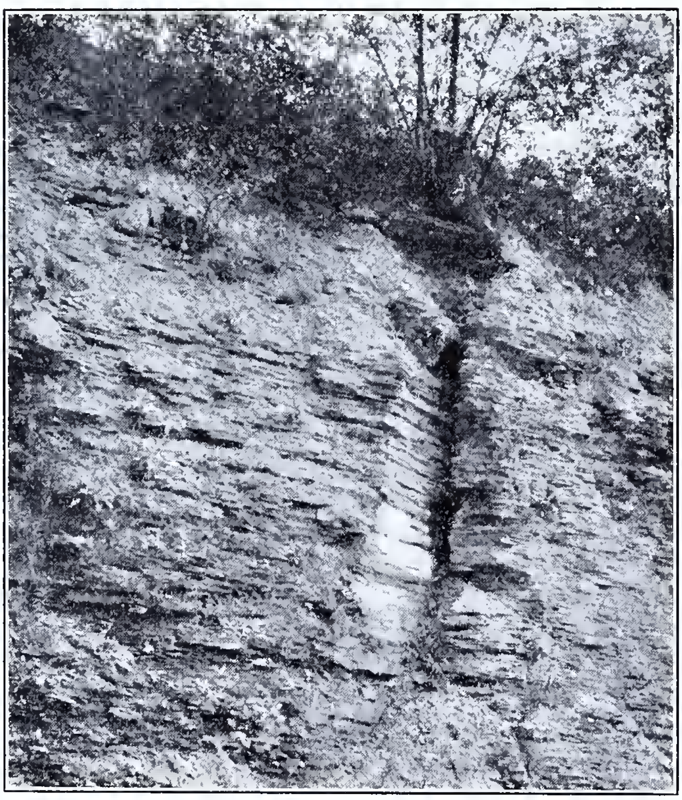


Figure 31. Shaly facies of upper portion of Mahoning sandstone, as exposed in road cut half a mile north of Callery, southwestern Butler County. Circulation of ground water is largely effected along joint planes such as the one that parts the bluff in the right-center of the view.

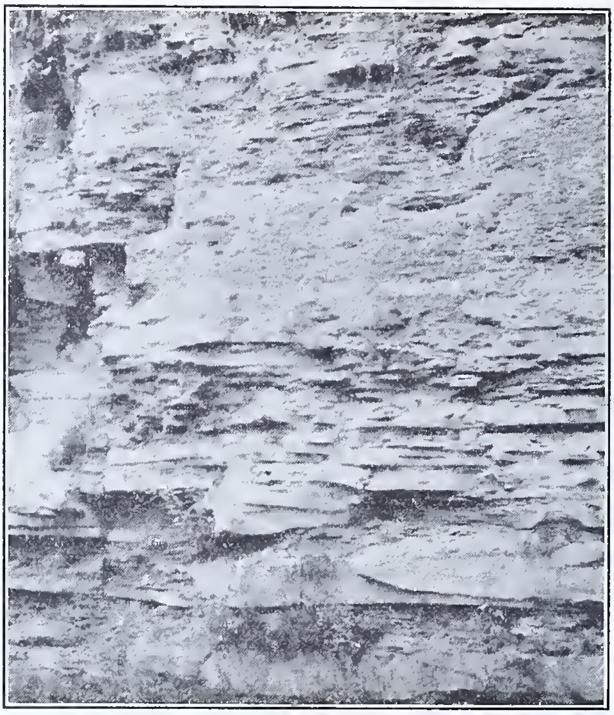


Figure 32. Interlaminated shales and thin sandstone lentils of upper portion of Mahoning sandstone, west of Allegheny River valley, a quarter of a mile north of Glenover, northeastern Allegheny County. This assemblage is typical of the "slate and shells" of the well driller.

graphic interval between the Brush Creek and Upper Freeport coal beds may contain only one layer of sandstone 10 feet thick.

The Mahoning sandstone is generally known to the driller as the Big Dunkard sand, in contrast to the overlying Saltsburg member, which is known as the Little Dunkard sand.

The shales which bisect the Mahoning sandstone range from a thin seam to 40 feet in thickness and vary greatly in lithology.

The several facies of the Mahoning sandstone are a rather trustworthy source of water in central Butler County and southward as far as Pittsburgh in Allegheny and northern Westmoreland Counties. Farther south, the member is also water-bearing in the deeply folded strata of south central and southeastern Westmoreland County and southeastern Fayette County.

Representative wells in the gently folded strata of the Allegheny Plateau are, for Butler County, No. 141 of Concord Township; 148 of Muddy Creek Township; 151 of Center Township; 155 of Oakland Township; 163 and 164 of Butler Township; 176 of Summit Township; 179 and 180 of Clearfield Township; 184 of Forward Township; 195 and 197 of Jefferson Township; 199 of Saxonburg Borough; 202, 204, 205, and 207 of Winfield Township; 208 of Cranberry Township; 213 and 216 of Adams Township; 219 and 221 of Clinton Township; also 223, 224, and 225 of Buffalo Township. In the district to the south, in Allegheny County, wells 242 and 244 of West Deer Township; 251 of Harrison Township; 252 of Franklin Township; 257 and 260 of Hamp-

ton Township; 1021 of Findley Township; 288 and 292 of Penn Township; and 319 of Elizabeth Township are typical. In the lower Allegheny-Ohio Valley of the same county the Mahoning sandstone contains fresh water, as in the R. R. Wilson No. 1 well of Leet Township, in the Bothwell well of Pittsburgh Borough, and in the George Orth No. 4 well of Ross Township. Deep wells in Baldwin, Jefferson, and Plum townships have also found the member water-bearing. Other typical wells farther east, in Westmoreland County, are Nos. 410 and 412 of Allegheny Township; 413 and 415 of Lower Burrell Township; 1062 of Washington Township; and 422 of Franklin Township.

Toward the south and west the member passes beneath deep cover, and is not usually reached by water-wells. Deep wells for gas or oil encounter water in the Mahoning sandstone at several localities, as in Cecil Township of Washington County, also in Dunkard and Richhill townships of Greene County. Usually in this region, however, the member is not water-bearing, as in wells 1021 of Findley Township, 1028 of Scott Township, and 1037 of Snowden Township, Allegheny County; in 1044 of Hanover Township, 1049 of Jefferson Township, and 1053 of Peters Township, Washington County; also in 1082 of Jefferson Township, 1090 of Whiteley Township, 1095 of Wayne Township, and 1097 and 1098 of Perry Township, Greene County.

The water-bearing properties of the member in the deeply-folded strata of the Allegheny Mountains in Westmoreland County is indicated by wells 457 and 465 of Hempfield Township; 474 of Ligonier Township; 498 of Mount Pleasant Township; and 505, 507, and 509 of Donegal Township. In the southern portion of this same district, in Fayette County, wells 602 and 607 of North Union Township; 631 and 633 of Wharton Township; and 642 of Markleysburg Borough are also representative. In the same county, however, the member is not water-bearing in well 605, North Union Township.

Throughout its geographic range and its several lithologic facies the Mahoning member varies considerably and in places erratically in water-yielding capacity. In the sandy facies water generally occurs in one or more coarse-grained permeable zones of irregular extent and of variable stratigraphic position within the member. Locally, chiefly along the axial parts of folds and where the member is not deeply buried, water occurs in joints. Where the permeable facies lies below the plane of surface drainage it stores water under moderate hydrostatic head and yields rather copiously to drilled wells, as at site 219. At this site five wells have been drilled for the railroad watering station, the diameters ranging from 8 to 14 inches, and the depths from 110 to 165 feet. When the first well was drilled prior to 1909 to a depth of 110 feet, the static level was about 59 feet below the surface. Another well which was drilled 14 inches in diameter and 160 feet deep in 1910 had an original tested ultimate capacity of 265 gallons per minute, the pump cylinder being set 155 feet below the ground surface. By 1917 the ultimate capacity of this well had decreased to 110 gallons per minute and the static level was about 110 feet below the surface. The other wells have had a similar history, the tested capacities in 1917 ranging from 25 to 98 gallons per minute. Mutual interference between the several wells while pumping is probable. Although the specific capacities of the wells, about 2.5 gallons per minute for each foot of drawdown, indicate that the mem-

ber is relatively permeable, the aggregate draft on the group of wells has exceeded the rate of percolation into their area of influence. Hence, the piezometric surface has been depressed locally. With this one exception, none of the wells which reach the Mahoning sandstone have been pumped more than 25 gallons per minute, so that little is known of variations in ultimate water-yielding capacity from place to place. Where the sandy facies lies above drainage level the hydrostatic head is small and the yield to drilled wells only a few gallons a minute. Moreover, much of the water may be semiperched, so that the ultimate capacity of a well is not increased by drilling to a greater depth. In the shaly facies of the member, water occurs in very small bedding plane channels and in joints, generally along the flanks of folds and under shallow cover, so that adjacent wells may find water at very different depths and have very different specific capacities. Perched and semi-perched bodies of ground water also occur at many places in these shaly beds. Moreover, the hydrostatic head is usually low, so that it is customary to drill below the water-bearing stratum in order that the well may have storage capacity which is adequate to meet periodic vigorous draft. Usually the capacity of wells which tap this facies is not more than 5 gallons per minute.

Locally the failure and subsidence of the roof above abandoned entrys in the Upper Freeport coal has been followed by drainage of the Mahoning sandstone and overlying strata and consequent failure of many wells. This has occurred at several localities in the vicinity of Freeport, as at Russellton in northeastern Allegheny County (See site 247, West Deer Township, Fig. 35), and elsewhere.

In southernmost Butler County and in the Allegheny Mountains in the eastern part of the area some wells which tap the Mahoning sandstone flow by artesian pressure. Typical wells in Butler County are No. 204 of Winfield Township and 216 of Adams Township. Well 197 of Jefferson Township also has a considerable natural flow, but the reported depth of the water-bearing bed and its equivalence to the Mahoning sandstone are open to question. In this district the southwestward-plunging folds serve as an artesian slope, and the location of the wells bears no relation to the axes. The artesian head of wells 204 and 216 is less than one foot above the surface of the ground, so that the area of potential artesian flow is limited to the creek bed in the vicinity of each well. Typical flowing wells in the eastern part of the area are No. 465 of Hempfield Township on the east flank of the Greensburg syncline, and No. 498 of Mount Pleasant Township on the east flank of the Latrobe syncline, in Westmoreland County; also 607 of North Union Township, Fayette County, on the east flank of the Uniontown syncline. Some miles to the northeast of well 607, wells of slight natural flow exist in the creek bed half a mile and more downstream from site 602. Again the artesian areas are somewhat local and, as in the case of the overlying Saltsburg sandstone, there is a relatively steep hydraulic gradient toward the axes of the synclines from either flank, so that large artesian pressures and large flows are not to be expected. However, flowing wells may be expected wherever coarse-grained facies of the member occur along the axes of the synclines, and the surface streams have cut below the level of wells 463, 498, 602, and 607.

The water from the Mahoning sandstone and its equivalent shales

is shown by analyses 164, 415, 422, 498, 509, and 633 to range from slightly to moderately concentrated. Where the member lies above drainage level, the waters are usually hard and are objectionable soap-consumers and scale-formers, as is represented by analysis 633, which is typical. Where the member lies considerably below drainage level, the waters are likely to be partly softened by exchange of bases, (see pp. 85-86), although this process does not proceed to completion in the Mahoning sandstone. Well 164, for example, tapped the member about 100 feet below drainage level and its water is only moderately hard and satisfactory for most domestic and industrial purposes. In many districts the water from the Mahoning sandstone contains so much iron that it is unsatisfactory for domestic purposes, as shown by analyses 422 and 509 (pp. 77, 79). Other wells and springs whose waters are iron-bearing are Nos. 151, 179, 180, and 184 of Butler County.

Wherever the member lies more than 100 feet below regional drainage base, and particularly in closed structural depressions, its waters are likely to be highly-concentrated brines, as in well 319 of Elizabeth Township, Allegheny County.

ALLEGHENY FORMATION

The arenaceous lower portion of the Conemaugh formation is underlain by the Allegheny formation, made up of shales, thin variable sandstones, some thin discontinuous limestone members, and several beds of coal and fireclay of local economic value. Its topmost member is the Upper Freeport coal, its basal member the local shale which underlies the Brookville coal and clay. The formation is even more variable in lithology and stratigraphy than any other of the Pennsylvanian series, so much so that no single section is representative. Shale constitutes the greater part of the Allegheny formation and in some sections sandstone is nearly absent. The shale is usually olive-green or drab on weathered faces in the upper two-thirds of the formation but in the lower third it is usually brown from the large content of iron oxide.

The Allegheny formation ranges between 250 and 370 feet in thickness within its outcrop area, and in general thickens northward with some secondary irregularities. This thickening amounts to 50 per cent in a distance of approximately 90 miles, being less than and opposite in direction to that of the overlying formations.

The sandstone members of the Allegheny formation are rather conspicuous water-bearers, especially the Clarion sandstone near the base. Where they lie below drainage level the coarse-grained and highly permeable parts of the sandstones yield as much as 300 gallons per minute to drilled wells. These coarse-grained facies are very discontinuous, however, and the permeability may vary greatly within a small area. Hence, they are distinctly inferior to the sandstone members of the overlying Conemaugh formation as sources of ground water. Wherever these members lie above drainage level, they supply many variable hillside springs along the outcrop and yield a few gallons per minute to wells. Locally the heavy-bedded and thick members seem to have been extensively fractured along the axes of folds, and the joints serve as ground-water conduits. The shale members of the formation, together with the associated beds of coal and

limestone, are altogether impermeable beneath continuous cover. Where they lie above drainage level along the flanks of folds, however, they yield household supplies from small bedding plane passages and joint planes, the capacity of most of the wells being less than 5 gallons per minute. In the shale members also much of the ground water is semiperched, so that successively deeper water-bearing members have less and less pressure head.

In some districts, in which it lies below drainage level, the Allegheny formation is not water-bearing throughout, as in wells 284 of Findley Township, Allegheny County, and 1044 of Hanover Township, Washington County. Such a condition is not general, however.

The fresh waters from the Allegheny formation are slightly to moderately concentrated, and moderately hard where the water-bearing beds are less than 50 feet below surface drainage level. Where the water-bearing beds lie at greater depth the waters may be relatively soft although the process of base exchange does not seem to be active in all places. Some waters contain so much dissolved iron that they are unsatisfactory for many purposes, particularly those from members which accompany beds of coal. Throughout the area that lies west of Chestnut Ridge the water from the Allegheny formation usually contains about 50 parts per million of chloride but in the Allegheny Mountains the water is nearly free of chloride. Where the water-bearing beds lie more than 100 feet below drainage level, much of the water is very highly concentrated brine.

UPPER FREEPORT COAL

The Upper Freeport coal lies from 500 to 750 feet below the Pittsburgh coal. This bed generally ranges between a few inches and 3½ feet in thickness; on the flank of Laurel Ridge in central Fayette County it is about 15 feet thick, including shaly partings. Within an oval-shaped area in eastern Allegheny County the bed is rather uniformly 6 to 7 feet thick and is known to mine operators as the Thick Freeport seam. The Upper Freeport coal is quite persistent throughout southwestern Pennsylvania except in the southern part of Butler County and adjacent areas, in which its horizon is occupied locally by the overlying Mahoning sandstone member or by shale. Many of these "faults" or "wants" in which the coal is missing are reported to have a closed circular or oval outline; others are ramifying bands.

In many parts of the region the Upper Freeport coal or its roof beds carry ground water, as in wells 156 of Oakland Township, Butler County and 1047 of Robinson Township, Washington County. In general, however, the water is of inferior quality because of its large content of dissolved iron and the member is shunned as a source of supply.

BOLIVAR FIRECLAY, BUTLER SANDSTONE, AND ASSOCIATED BEDS

Although the interval between the Upper Freeport coal and the underlying Lower Freeport coal is predominantly shaly, a sandstone stratum, known as the Butler (or Upper Freeport) sandstone, fills a part or the whole thereof over extensive areas in Butler County and northern Allegheny County. In the type region about the city of Butler, the member is a coarse-grained reddish-white or gray massive

sandstone about 50 feet thick and is separated from the overlying coal by not more than a few feet of clay and shale. Locally it is conglomeratic and is identical in appearance with the Mahoning sandstone above. Farther south, in Allegheny and northern Westmoreland counties, the sandstone becomes thin-bedded and passes into sandy shale interbedded with thin micaceous sandstone lentils or into soft clay and shale. The type phase is locally recurrent eastward from the Uniontown-Latrobe syncline (Pl. I) in eastern Fayette and Westmoreland counties. In its shaly phase the member is usually accompanied by the Upper Freeport limestone which lies a few feet below the coal. This limestone ranges between 2 and 28 feet in thickness, although it does not exceed 10 feet in most places. It is always ferruginous and locally carries sufficient nodular or disseminated iron carbonate so that it has been used as an iron ore.

In Westmoreland County along Conemaugh River the Butler sandstone is absent and a mass of fireclay locally more than 20 feet thick is found below the Upper Freeport limestone. This is known as the Bolivar fireclay, from the town of that name.

The type phase of the Butler sandstone is a conspicuous waterbearer throughout its geographic range. Typical wells in Butler County are Nos. 138 and 140 of Clay Township, 142 and 1003 of Concord Township, 144 of Karns City Borough, 154 of Oakland Township, 172 of Butler Township, and 189 of Forward Township. In northern Allegheny County, well 240 of West Deer Township is typical. In eastern Westmoreland County the type phase supplies wells 445 of Fairfield Township, 467 of Hempfield Township, 473 of Ligonier Township, and 502 of Mount Pleasant Township. Farther south it is entered by well 641 of Henry Clay Township, Fayette County. The permeable portions of the member are somewhat lenticular and discontinuous so that the water-yielding capacity varies from place to place, although wells are usually successful in obtaining domestic supplies, even where the member lies above drainage level. The draft on any of the wells is not known to exceed 5 gallons per minute, so that the ultimate water-yielding capacity of the member is not known.

The shaly facies of the Butler sandstone horizon is a somewhat erratic source of small water supplies in the vicinity of its outcrop, circulation taking place along small bedding plane passages and to a minor degree along joints. Representative wells in Butler County are No. 171 of Butler Township, 174 and 175 of Summit Township, and 212 of Callery Borough. In Allegheny County wells 248 of Fawn Township, 263 of Elder Township, and 273 of Harmar Township are representative, as is also well 491 of Mount Pleasant Township, Westmoreland County. Adjacent wells may differ greatly in depth and water-yielding capacity; in none is water encountered under large head, and usually the yield does not exceed 2 gallons per minute. The bedding plane and joint conduits which supply these wells do not, however, continue beneath deep cover and, under such conditions, the beds may fail as a source of water, as in well 163 of Butler Township, Butler County. In general the Upper Freeport limestone is not a valuable water-bearer although locally bedding plane channels at its upper or lower surface yield copiously, as in wells 160 of Connoquenessing Township of Butler County and 1072 of Hempfield Township, Westmoreland County.

The water from the beds of the Butler sandstone horizon is shown by analysis 248 (p. 74) to be moderately concentrated and moderately hard, and of fair quality for most household and industrial purposes. Analysis 154 (p. 72) represents a mixture of a water similar to No. 248 with a concentrated brine that is probably derived from a near by oil well and seeps into the well through faulty casing. It is unsatisfactory for household use. Most of the waters from the beds of this formation contain very little dissolved iron.

In the western part of the area in Allegheny and Greene counties, the Butler sandstone is locally persistent beneath deep cover, being a part of the Gas sand of the well driller. Little is known, however, of its water-bearing properties within that district.

LOWER FREEPORT COAL AND LIMESTONE

Although the Lower Freeport coal and limestone carry small bodies of ground water in some localities, they are carefully avoided as a source of supply inasmuch as the large iron content renders the water quite undesirable for ordinary uses.

FREEPORT SANDSTONE

In extensive areas in Butler and Allegheny counties the Freeport sandstone ranges from 30 to 70 feet thick, but attains a maximum of 120 feet on Ohio River to the west. It varies from a massive bed, that is locally conglomeratic through a thin-bedded flaggy fine-grained sandstone, to a laminated sandy shale. Where thickest, the Freeport sandstone rests directly upon the underlying Upper Kittanning coal. Although it is heavy-bedded at some localities it cannot be recognized at others.

The coarser phases of the Freeport sandstone are moderately permeable and, where they lie below drainage level, ground water is retained under moderate hydrostatic pressure and drilled wells may yield as much as 25 gallons per minute. The lowest beds of the member are especially likely to be water-bearing. Inasmuch as the member varies widely, and at times abruptly, in texture and permeability, it is not a dependable source in any untested locality. Representative wells in Butler County are Nos. 137 of West Sunbury Borough and 188 of Forward Township. For Allegheny County, well 249 of Fawn Township is typical. To the east, in Westmoreland County, the member is water-bearing in wells 440 of Derry Township, 1074 of Unity Township, and 504 of Cook Township. Moreover, the casing record of well 1068, of Hempfield Township suggests that the member is also water-bearing at that locality. In Fayette County, wells 634 and 636 of Wharton Township and 640, near Henry Clay Township are also typical. Little is known of the water-yielding capacity of the member beneath deep cover in the southwestern part of the region, although it is noted as water-bearing in the records of some deep wells, as in No. 1020 of Moon Township, Allegheny County and in 1085 of Aleppo Township, Greene County.

Of the representative wells that tap the Freeport sandstone, No. 440 of Westmoreland County flowed slightly by artesian pressure at the time of drilling in October, 1926. This well is on the steep western slope of Chestnut Ridge about 350 feet above the valley floor and

about half a mile west of the outcrop of the water-bearing bed. Presumably the artesian condition exists because the permeability of the stratum decreases rapidly toward the west so that hydrostatic head may be maintained locally in the vicinity of the outcrop. Although no other flowing wells are known to tap the Freeport sandstone it is possible that an artesian condition exists in the member along the axes and flanks of the syncline in the eastern part of the area wherever the permeability is large.

Analysis 249 (p. 74) is representative of the quality of the water from the Freeport sandstone where it lies below drainage level. This water is moderately concentrated and very soft, although it would be likely to foam if used as a boiler feed. In most places the water from this member is nearly free from dissolved iron, but locally, especially in those districts in which the overlying Lower Freeport coal is thick, it contains so much iron that it is likely to stain linens and household utensils.

UPPER KITTANNING COAL AND ASSOCIATED ROCKS

The Upper Kittanning coal and its associated shales are not readily permeable, although in the vicinity of the outcrop small bedding plane channels supply drilled wells of household size and some hillside springs. Of these No. 153 of Oakland Township and 186 of Forward Township, Butler County, are typical. On the whole, however, this horizon is not a sure source of adequate supplies.

Many small and scattered bodies of ground water occur at the upper and lower surfaces of the Middle Kittanning coal in northern Butler County, where the bed lies above drainage level. In most places the head is small and the yield is small and variable from season to season. Well No. 103 of Mercer Township, Butler C unty, is representative. Analysis 103 (p. 71) shows that this water is slightly concentrated and relatively soft although it is quite unsatisfactory for most purposes, on account of the large content of iron. Where the coal bed passes beneath continuous cover its typical facies is not usually water-bearing, although in central Butler County it seems to occur as a permeable carbonaceous shale enclosed by sandy beds and is tapped by several wells, of which No. 168 of Butler Borough is typical. Analysis 168 (p. 72) shows that the water from this facies of the member is rather soft although it is moderately concentrated.

WORTHINGTON SANDSTONE

This lenticular sandstone of variable texture fills part of the interval between the Upper and Lower Kittanning coals and locally replaces the Middle Kittanning coal. The portion of the Worthington sandstone which lies below the horizon of the Middle Kittanning coal is especially subject to lateral gradation into shale, but the upper portion is a moderately persistent sandstone at least 15 to 30 feet thick. Where it fills the greatest stratigraphic interval, however, the member is about 100 feet thick. In the eastern part of the region the beds of this horizon are generally variable in texture, but along the western flank of the Laurel Hill anticline (Pl. I) in Fayette County a sandstone facies reappears.

Eastward from the meridian which lies about 2 miles east of Butler,

the Worthington sandstone is moderately persistent in type phase and is a rather trustworthy source of water supplies of moderate size. Typical wells in Butler County are Nos. 129 and 130 of Washington Township, 158 and 159 of Millerstown Borough, 1006 of Donegal Township, and 222 of Clinton Township. In the immediately contiguous portion of Allegheny County, well 243 of West Deer Township also reaches the member. Even within this district, however, the member is variable in permeability, the specific capacity of drilled wells ranging widely up to a maximum of about 5 gallons a minute per foot of drawdown in well 159. Farther west the member passes into a complex assemblage of lenticular sandstones and shales whose permeability varies greatly and perhaps abruptly. In some places, the beds of this horizon are shaly and carry only small semi-perched bodies of ground water above drainage level or are not water-bearing where they lie beneath continuous cover. Representative wells and hillside springs of Butler County which are supplied by this shaly facies of the member are No. 102 of Mercer Township, 113 of Venango Township, 136 of Brady Township, 139 of Clay Township, 149 of Franklin Township, 162 and 169 of Butler Township, and 182 and 183 of Jackson Township. The capacity of such wells is generally less than two gallons per minute. At some localities where the member lies above drainage level, its semi-perched water has been depleted by the drilling of many deep oil wells which are not tightly cased near the surface of the ground. Consequently, shallow wells have failed in course of time, as Nos. 113 and 130. To the east, in the district of relatively deep folding, the member is water-bearing in wells 1072 of Hempfield Township, 1073 of Unity Township, and 508 of Donegal Township, Westmoreland County. Well 442 of Derry Township is reported to have encountered water at this horizon, although presumably the main yield was obtained at greater depth. Farther south, in Fayette County, the member becomes more persistent and supplies wells 578 and 579 of Saltlick Township, 590 and 591 of Springfield Township, n03 of North Union Township, and 632 of Wharton Township. Nowhere within this district has the draft upon a well exceeded the demands of a household supply, so that the ultimate water-yielding capacity is not known. Within Fayette County, however, the member is moderately permeable over extensive areas.

The Worthington sandstone supplies several flowing wells along the axis of the Youghiogheny syncline near well 591, although the head is small, and the yield less than 10 gallons per minute. Other potential areas of artesian flow very probably exist along the axes of the deeper synclines of this district where the permeability of the member is sufficiently high and the streamways have cut below the piezometric surface. It is likely that there is a relatively steep hydraulic gradient toward the axis of each syncline from either flank, however, and that the artesian head is small at all localities.

The type facies of the Worthington sandstone is probably most persistent where it lies beneath deep cover in Washington and Greene counties, in which district it is water-bearing in many deep wells. Typical of these in Washington County are wells 359 of Union Township, 1043 of Hanover Township, and 1049 of Jefferson Township. In Greene County, 1077 of Morgan Township, 1079 of Center Township, 1080 of Franklin Township, 1085 of Aleppo Township, 1086 of Jackson Township, also 1099 and 1100 of Perry Township are repre-

sentative. In the Uniontown syncline of central Fayette County, the member is also reached by well 605 of North Union Township. With the exception of well 359, which has a reported ultimate capacity of 35 gallons per minute, the potential capacity is not known. In these districts the member, which is known as the Salt sand or First Salt sand, contains a very concentrated brine and in many wells is the first water-bearing stratum encountered more than 300 feet below the surface of the ground.

Analyses 159 and 578 (pp. 72 and 81) represent slightly to moderately concentrated and relatively hard calcium-magnesium bicarbonate waters from the Worthington sandstone. Throughout the region, the waters of this sandstone contain more dissolved iron than any of the overlying strata, so that in many districts they are unsatisfactory for laundering and some other purposes. This is particularly true of those districts in which the Kittanning coals are thickest and of those wells in which the coals have not been thoroughly cased off, as in the vicinity of wells 149, 508, 578, and 591. Wherever the member lies at or immediately below drainage level in the area west of Chestnut Ridge, the water contains about 50 parts per million of chloride. Farther east, in the region of relatively close folds, ground water circulates more rapidly and the chloride content is small, as in analysis 578. Where the member lies below drainage level it contains very concentrated brine.

LOWER KITTANNING COAL AND CLAY

The Lower Kittanning coal lies in the average section 200 feet below the top of the Allegheny formation. It is the most uniform in thickness and quality of all coal beds of the formation. The Lower Kittanning coal is underlain by a persistent bed of fireclay, usually between 2 and 12 feet in thickness.

The ground water which accompanies these beds near the outcrop usually contains much dissolved iron, and hence, is unsatisfactory for domestic use. Where the beds lie beneath continuous cover they are not usually water-bearing, although locally water is found at the upper or lower surface of the coal, as in wells 1046 and 1047 of Robinson Township, 1053 of Peters Township, and 1056 of Nottingham Township, Washington County.

KITTANNING SANDSTONE

The Lower Kittanning coal or fireclay is underlain by the Kittanning (Lower Kittanning) sandstone, at least in Butler County and the greater part of Allegheny County. This sandstone varies from 10 to more than 60 feet thick, and is typically somewhat massive, coarse or medium-grained, and grayish to pinkish-white in color. Locally the type phase grades into thin-bedded sandstone and interbedded shale and clay.

The Kittanning sandstone is much superior to the Worthington sandstone as a source of ground water throughout Butler County, for generally it is more permeable. Locally, however, its permeability varies greatly within small areas. Over much of the eastern and southern portions of the region, however, it is relatively impermeable or is not water-bearing. Representative wells in Butler County which tap the member are No. 115 of Eau Claire Borough, 116 of Venango Town-

ship, 130 of Washington Township, 140 of Clay Township, 162, 166, 169, and 170 of Butler Township, and 187 of Forward Township. Near Butler the member is very coarse-grained and even pebbly so that its water-yielding capacity is relatively large, as in well 162, which has a specific capacity of one gallon a minute per foot of drawdown. Elsewhere within the county the draft is not known to have exceeded 5 gallons per minute from any well so that the ultimate water-yielding capacity is unknown. Where the type facies of the member lies below drainage level, however, water is retained under moderate hydrostatic head and wells for domestic supply are ordinarily successful. In this same vicinity, however, the member may pass abruptly into sandy shales whose water-yielding capacity is extremely low. In well 163 for example, the horizon of the Kittanning sandstone was entirely filled by impermeable shale, although wells drilled about half a mile to the northeast and well 169, which is located a mile and a quarter to the southeast, found it to be pebbly and highly permeable. Similarly, well 167 of Butler Borough failed to find the member water-bearing as it was in No. 166, located half a mile to the north.

In Westmoreland County, the shaly facies of the member carries ground water beneath thin cover and for the most part above drainage level, as in well 501 of Mount Pleasant Township of Westmoreland County. Other members being more productive, however, the beds of this horizon are not highly developed. Southward and westward from Pittsburgh the member is deeply buried and is known only from the records of deep wells. On the whole, the type facies seems less persistent in this district than the Worthington sandstone above, although the two are not always differentiated in the records. In a few wells it is found to be water-bearing, as in No. 1094 of Gilmore Township, Greene County.

It is reported that many wells that tapped the Kittanning sandstone in the bed of Connoquenessing Creek in the vicinity of Butler formerly flowed by artesian pressure. However, the artesian head was dissipated during the eighties and nineties when so many oil wells were drilled in that district, so that none of the wells that tap the Kittanning sandstone flow at present.

In general the water from the Kittanning sandstone is similar in chemical composition to that from the overlying Worthington sandstone, being moderately concentrated and moderately hard. However, it is generally nearly free from dissolved iron. In Butler County the water from the Kittanning sandstone generally contains less than 100 parts per million of chloride, although locally, in the petroliferous districts, brackish waters are encountered where the member lies 100 feet or more below surface drainage level. In some of these brackish waters the chloride probably represents brine from near by oil wells which has seeped into the shallow water-bearing members of the water wells through defective or inadequate casings. Farther south within the Kanawha section, the Kittanning sandstone generally lies below regional drainage level and contains highly concentrated brine.

VANPORT LIMESTONE

Within its outcrop area in Butler County and adjacent regions the Vanport limestone occurs from 45 to 75 feet below the Lower Kit-

tanning coal and clay and 245 to 260 feet below the top of the Allegheny formation. It ranges from 1 to 20 feet in thickness and is generally massive or thick-bedded. Locally it comprises several thin layers separated by partings of shale. The Vanport member is rather persistent in Butler and Allegheny counties, although locally it is thin and shaly. In eastern Butler County and elsewhere the limestone locally contains at its top about 12 inches of iron oxide and carbonate, the Buhrstone ore of former days, and is accompanied by nodular iron carbonate in the underlying shales. These associations gave to the member its former name Ferriferous limestone.

The limestone can generally be identified with certainty in most of its outcrops, so that it is a trustworthy key bed in tracing stratigraphy and structure.

The typical massive facies of the Vanport limestone is not permeable and, consequently, is not usually water-bearing beneath deep cover. Where the member is not more than 50 feet below the nearby surface drainage ways, however, small bodies of ground water occur at its upper and lower surfaces, near the outcrop. Locally the member is permeable where solution has formed ground water conduits along joint planes and in the shaly layers of the thin-bedded facies. However, if the member lies above drainage level, such conduits are not likely to be saturated and, if entered by the drill, may drain perched or semi-perched bodies of ground water in overlying shaly rocks.

Many small and variable hillside springs occur along the outcrop of the Vanport limestone in northern Butler County and drilled wells reach it beneath cover. Typical of these are No. 101 of Mercer Township, 147 of Muddy Creek Township, and 173 of Summit Township. Farther south the member passes beneath continuous cover and generally is not water-bearing. In Westmoreland and Fayette counties, however, the member crops out along the flanks of the Chestnut Ridge and Laurel Hill anticlines where it supplies many hillside springs and drilled wells of household size, such as No. 573 of Bullskin Township, Fayette County.

The water which accompanies the Vanport limestone is generally moderately concentrated, hard, and almost free of dissolved iron, as is indicated by analysis 101 (p. 71). Locally, however, the water from ferruginous beds which accompany the limestone contains so much iron that it is wholly unsatisfactory for most purposes.

UPPER AND LOWER CLARION COALS

The Vanport limestone is underlain by soft drab-colored shales interbedded with lentils of coarse sandstone 1 or 2 feet thick, and enclosing one or two thin beds of coal.

Locally the beds of this horizon supply many small hillside springs along the outcrop and yield small water supplies to drilled wells such as No. 112 of Venango Township, Butler County. At most places, however, they contain little or no water.

CLARION SANDSTONE

In the greater part of the region the Clarion coal is underlain by variable soft sandy shales but in the Allegheny River section along the eastern edge of Butler County, a hard massive sandstone from

5 to 40 feet thick lies between the Clarion and Brookville coals and about 45 feet below the top of the Vanport limestone. This is the Clarion sandstone.

The Clarion sandstone is probably the most consistent water-bearing member of the Allegheny formation, at least within the area covered by this report, especially where it is thickest and is nearly continuous with the underlying Pottsville formation. In the district north of Butler the few outcrops of its horizon are marked by many permanent hillside springs of variable flow and small magnitude, such as No. 110 of Venango Township. Representative wells which reach the type facies are No. 124 of Slippery Rock Township, 134 and 135 of Brady Township, and 166 and 167 of Butler Township. Well 125 of Slippery Rock Township, also found the member to be water-bearing. Wherever in this region the type facies of the member lies below drainage level, water is retained under considerable hydrostatic head and the water-yielding capacity is moderately large. For example, the specific capacities of wells 9 and 10 of the Citizens Mutual Water Company of Butler, at site 167, are about 0.8 gallon a minute per foot of drawdown although they are but 5 feet apart. These wells are pumped at the joint rate of 40 gallons per minute about 12 hours daily. Other wells at this site and at site 166 yield from 8 to 15 gallons per minute, the specific capacities being unknown. The water-yielding capacity of the member at other places in the county is not known but in view of the variable texture of all members of the Allegheny formation it presumably ranges widely. In the northwestern part of Butler County the Clarion sandstone is locally shaly although it is moderately permeable, as in well 146 of Muddy Creek Township.

Where the Clarion sandstone is near the surface in northern Butler County, it generally contains a moderately concentrated and relatively hard calcium bicarbonate water that is nearly free from dissolved iron. Where the member lies somewhat below drainage level, however, its water may be highly concentrated and slightly salty as is shown by analysis 167 (p. 72). In southern Butler County and farther south the Clarion sandstone is deeply buried, is not everywhere water-bearing, and carries only highly concentrated brines. Typical wells are No. 1011 of Clinton Township, Butler County; 1021 of Findley Township, Allegheny County; 1094 of Gilmore Township and 1096 of Wayne Township, Greene County.

The Clarion sandstone is also water-bearing in central Westmoreland County, as is indicated by wells 407 of Allegheny Township and 430 of Jeannette Borough. Of these two wells, 430 encounters water under moderate hydrostatic head, although it is located on the axis of the gently-plunging Grapeville anticline (Pl. I). The yield is 250 to 300 gallons per minute, and the specific capacity about 3 gallons per minute for each foot of drawdown. Several other wells on the same plot of ground, however, have different specific capacities, the minimum being only a few tenths of a gallon per minute for each foot of drawdown. An equally large range in the permeability of the member probably exists elsewhere.

In this district the Clarion sandstone contains highly concentrated brackish water where it lies below surface drainage level, as is shown by analysis 430 (p. 77). Such brackish water is wholly unfit for any

ordinary use other than for cooling condensers and similar industrial apparatus.

CRAIGSVILLE AND BROOKVILLE COALS

Between the Clarion sandstone and the base of the Allegheny formation are one or more coal beds, sandstone lenses and shale. These strata measure only a few feet thick in some places, and elsewhere up to 100 feet. The coal may contain much pyrite. The variable Brookville coal is at or just above the base of the Allegheny formation and beneath the thin, discontinuous Craigsville coal.

POTTSVILLE FORMATION

Within the six counties covered by this report the Pottsville formation ranges in thickness from 65 to 250 feet, the minimum being near Conemaugh Gap in northeastern Westmoreland County and the maximum in the Ohio Valley of western Allegheny County. Hence the formation thickens toward the west within this area, although the relief of the unconformity at its base is so great that this relation may not hold in a small area. When the characteristics of the Pottsville in the Appalachian trough are viewed broadly, however, it is seen that the regional thickening is toward the southeast.

The Pottsville formation crops out in the extreme northwestern corner of Butler County in the valley of Slippery Rock Creek, and in the northeastern corner of the county in the valleys of Allegheny River and its tributaries, Little Scrubgrass Creek and Bear Creek. Farther south it does not crop out at any point in the area west of Chestnut Ridge. In the Allegheny Mountain district to the east the formation has a rather sinuous outcrop along the flanks and locally on the crests of the Dulaney-Chestnut Ridge anticline and the Laurel Hill anticline.

HOMEWOOD SANDSTONE

The uppermost member of the Pottsville formation is known as the Homewood sandstone, after the type locality in Beaver County. At this place the member consists of 65 feet of coarse-grained massive sandstone underlain successively by shale (the Mercer shale member), which ranges from 0 to 15 feet thick, and by the Connoquenessing sandstone. Locally these two sandstones present what is apparently a single stratum 150 feet thick.

The Homewood sandstone is usually grayish-white to reddish, massive or heavy-bedded, coarse-grained and pebbly, and loosely cemented. It varies abruptly in thickness and grades in part to thin-bedded sandstone or sandy shale. It ranges in thickness from a few feet to 100 feet within the area and in general thickens toward the southeast. It is about 40 feet thick in eastern Butler County, 60 to 75 feet in the Latrobe basin of Westmoreland County, and 30 to 80 feet at its outcrop along Youghiogheny River in Fayette County.

The Homewood sandstone is probably the most consistent water-bearing member of the entire Pennsylvanian series, its texture and permeability being relatively uniform over extensive areas. It lies within easy reach of the drill in the northern half of Butler County and is tapped by wells 104, 105, and 106 of Marion Township; 109 and 111 in and near Venango Township; 114 of Eau Claire Borough; 118, 119,

120, and 122 of Slippery Rock Township and Borough; 128 of Washington Township; 131 and 132 of Bruin Borough; also 140 of Clay Township. In the southwestern portion of the county the member is reached by wells 183 of Jackson Township and 185 of Forward Township, both of which are located on the flanks of the Brush Creek anticline. Farther east, well 206 taps the member near the axis of the Kellersburg anticline. Throughout this district the yield to drilled wells is from 5 to 20 gallons per minute wherever the member lies below drainage level. The specific capacities are probably less than half a gallon per minute for each foot of drawdown.

In the eastern part of the area, where the rocks are more closely folded (Pl. I), the Homewood sandstone is also water-bearing, although its permeability is more variable and the geologic structure exercises a direct control over the pressure head. In the Chestnut Ridge and Laurel Hill district it supplies many hillside springs along the outcrop. In Westmoreland County the member is penetrated by well 1072 of Hempfield Township and is the chief aquifer in well 442 of Derry Township. At well 442 the sandstone is relatively very permeable, for the specific capacity is about 10 gallons per minute for each foot of drawdown. At site 430 of Jeannette Borough, well No. 6 obtained a large yield from the member where it was between 325 and 395 feet below the surface, although it is reported that another well, No. 7, has an ultimate capacity of only a few gallons per minute. At this site, on the axis of the Grapeville anticline, the hydrostatic head is only moderate. Farther south, the Homewood member is tapped by wells 635 of Wharton Township, and 638 near Henry Clay Township of Fayette County.

In the southwestern part of the area the Homewood member is deeply buried and, although water-bearing rather generally, contains only highly concentrated brines. Typical deep wells which penetrate the member are: in southern Butler County, 1009 of Jefferson Township; in Allegheny County, 1013 of West Deer Township, 1017 of Elder Township, 1018 of Tarentum Borough, 1020 of Moon Township, 1021 of Findley Township, and 1037 of Snowden Township; in Washington County, 1050 of Cross Creek Township and 1052 of Peters Township; finally, in Greene County, 1082 of Jefferson Township, 1089 and 1090 of Whiteley Township, 1093 of Gilmore Township, 1095 and 1096 of Wayne Township, and 1097 of Perry Township. In Greene County especially the member is water-bearing at most places and the salt water rises as much as 1,200 feet above the member in the major synclines and within as little as 200 feet below the surface in the valleys.

There are within the area two districts of potential artesian flow from the Homewood sandstone: first, the area of very slightly folded and southward-dipping rocks in Butler County, and, second, the area of relatively closely folded beds in Westmoreland County. Typical flowing wells in Butler County are No. 105 of Marion Township and 109 near Venango Township. In neither of these is the artesian head at the ground surface more than a few feet or is the flow large; neither are large artesian pressures and rates of flow to be expected within the area. The fragmentary data available indicate that the piezometric surface slopes southward about 6½ feet per mile. That being the

case, the approximate area of artesian flow embraces the beds of Slippery Rock Creek and its principal branches below 1,210-feet altitude, that is, westward from the meridian passing through the city of Butler. Further, it embraces the beds of Connoquenessing Creek and its principal tributaries—Bonnie Brook, Coal Run, and Thorn Creek—southward from the vicinity of well 143 to the latitude of Saxonburg and westward to the boundary of the county. Whether or no it embraces also any portion of the Allegheny Valley is not known. Throughout most of this district the Homewood member forms essentially a lithologic unit with the underlying Connoquenessing and Burgoon sandstones, the water in three divisions of the unit being under approximately the same pressure head. Hence the area of artesian flow as approximately outlined above, applies also to the underlying members. Of the Westmoreland County district, a typical flowing well is No. 442 of Derry Township.

It is not possible from the little data available to bound the area of potential artesian flow even approximately, although it doubtless includes many of the lowest portions of the terrane adjacent to the axes of the synclines (Pl. I). It is probable, however, that there exists a steep hydraulic gradient toward these axes from either flank so that large pressure heads are not to be expected. Toward the south, in Fayette County, the piezometric surface seems to lie everywhere beneath the land surface so that flowing wells are not probable.

The water from the Homewood sandstone, by analyses 105, 442, and 635 (pp. 72, 78, 81, and Fig. 33), ranges from slightly to moderately

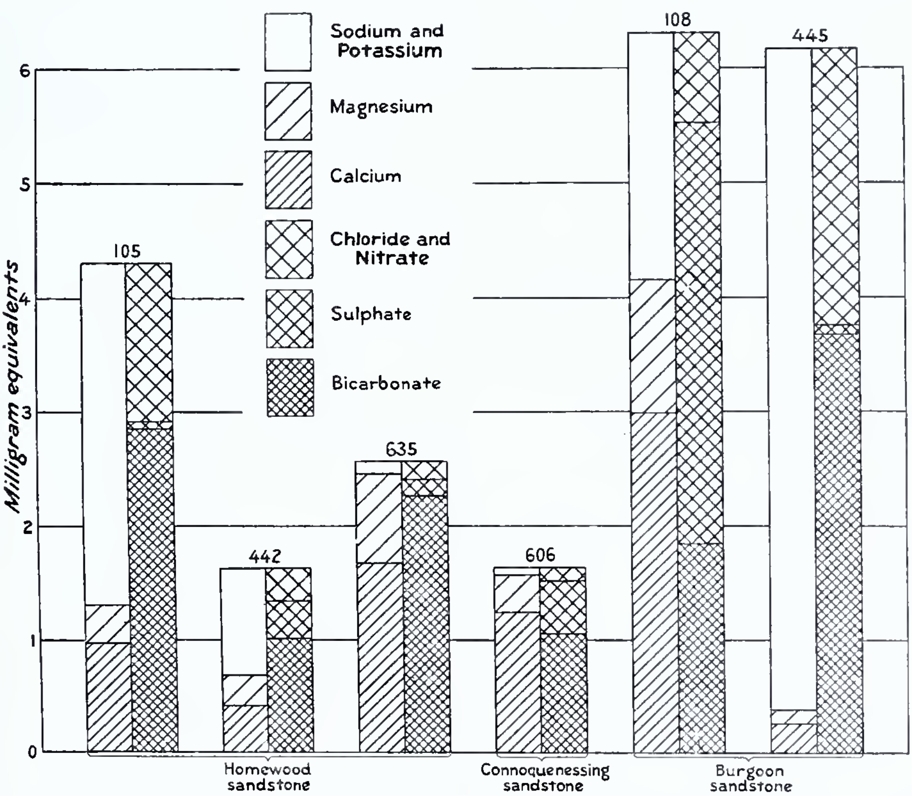


Figure 33.—Chemical character of waters from the Homewood, Connoquenessing, and Burgoon sandstones.

concentrated. In general, the member contains a moderately hard calcium bicarbonate water where it lies above drainage level, but in many places where it lies at moderate depth it contains water that has been partly softened by exchange of bases. A partly softened water is represented by analysis 105. Generally the water from the Homewood sandstone is nearly free from dissolved iron, except where the coals and shales at the base of the overlying Allegheny formation or the underlying Burgoon sandstone is ferruginous. Where the Homewood sandstone lies below drainage level it generally contains brackish water, such as is represented by the sample from well No. 6 at site 430 (p. 77), or highly concentrated brine.

MERCER SHALE

The Homewood sandstone is underlain by a group of dark gray or brown shales which enclose thin lentils of sandstone and limestone, several thin beds of coal, and at some places fireclay. These constitute the Mercer shale member, or Mercer "group" as the beds have been called in some reports. This member varies in thickness from 6 inches to 50 feet and in many places varies inversely in thickness with the Homewood sandstone above and with the Connoquenessing sandstone below.

CONNOQUENESSING SANDSTONE

The basal member of the Pottsville formation in most parts of southwestern Pennsylvania is the Connoquenessing sandstone. This sandstone ranges from 0 to 110 feet in thickness, the maximum being exposed in the Youghiogheny River section north of Ohiopyle. It is 30 to 50 feet thick in eastern Butler County, from 5 to 100 feet thick in the Ohio Valley, and not more than 25 feet thick in the Latrobe basin. Local differences in thickness may be relatively large and abrupt. The typical phase of the Connoquenessing sandstone is light-gray or white, irregularly bedded, coarse-grained, and contains some conglomeratic lentils. At many places it is made up of white quartz grains loosely consolidated by a siliceous cement and is quite free from impurities. On the whole, however, it is much more variable in lithology than the overlying Homewood member and locally is replaced in part or in whole by lenticular bodies of shale.

As a source of ground water supplies the Connoquenessing sandstone is distinctly inferior to the overlying Homewood member in Butler County, inasmuch as it is rather variable in permeability. The type phase, however, is relatively permeable and may be tapped in conjunction with the overlying Homewood member, as in wells 107 of Marion Township, 121 and 123 of Slippery Rock Township, and 132 of Bruin Borough. In northern Allegheny County, well 241 of West Deer Township obtained a small yield in the shaly facies of the member. In the eastern part of the region, however, the Connoquenessing sandstone is an outstanding water-bearer and supplies many hillside springs and drilled wells. Typical wells are 574 of Bullskin Township, 606 and 608 of North Union Township, and 612 of Ohiopyle Borough, Fayette County. Where it lies beneath deep cover, the Connoquenessing sandstone is water-bearing in many localities although less generally than the Homewood member above. Wells 1042 of Hanover Township, Washington County; 1068 and 1070 of Hempfield

Township, Westmoreland County; also 1087 of Jackson Township and 1092 of Springhill Township, Greene County, are representative.

The water from the Connoquenessing sandstone is similar in chemical character to that from the overlying Homewood sandstone. Analysis 606 (p. 81, and Fig. 33) is representative of the hard calcium bicarbonate waters where the member lies at shallow depth.

MISSISSIPPIAN SERIES—MAUCH CHUNK FORMATION

In the southwestern part of the State, the Mauch Chunk consists of red, gray, or green shales interbedded with several limestones and at least two sandstone members. Although in the region covered by the present report the formation crops out only along the higher anticlines of eastern Westmoreland and Fayette counties, as shown by the geologic may (Pl. I), its red shale beds are known from driller's records of many deep wells. Within this region, the Mauch Chunk ranges from 0 to 310 feet in thickness. Its maximum thickness occurs along the Pennsylvania-West Virginia boundary, in Fayette and Greene counties. Thence the formation thins northward and westward and wedges out along a rather sinuous line which passes eastward across northern Washington County, passes a few miles south of Pittsburgh, then swerves northeastward and leaves the region in the vicinity of Saltsburg.

The beds of the Mauch Chunk formation are generally water-bearing where they lie beneath deep cover. They crop out only in the relatively thinly populated Chestnut Ridge and Laurel Hill districts—in which springs fed by overlying and underlying permeable sandstones abound—so that their water-bearing properties near the outcrop have not been tested by wells.

GREENBRIER LIMESTONE

The Greenbrier limestone, known to the driller as the Mountain lime, is a lenticular bed which appears in western Pennsylvania and grades southward and westward into a thick group of interlaminated limestones, shales, and sandstones. Within its outcrop area along Chestnut Ridge anticline, in eastern Fayette County, the Greenbrier member is made up of thin beds of pure bluish-green limestone which grade upward into calcareous olive-green shale, its maximum thickness being about 30 feet. To the north, in Westmoreland County, the member pinches out, its extreme feather edge being penetrated by wells drilled in the vicinity of Kingston, about three miles southeast of Latrobe.

In Greene and Washington counties the Greenbrier is deeply buried but its extent and lithologic character have been traced in the logs of many deep wells. In this district the member comprises four subdivisions, which are known to drillers in descending order as Little lime, Maxton sand, "Pencil cave," and Big lime or Mountain lime. In western Greene County, this quadruple member is as much as 110 feet thick but it thins northward and wedges out in west-central Washington County.

LOWER SHALE BEDS

In the Chestnut Ridge anticline of Fayette County the Greenbrier limestone is underlain by about 50 feet of red shale, but the beds are of limited extent and thin northward and westward by overlap. They are not recorded in the logs of drilled wells in Greene and Washington counties.

LOYALHANNA LIMESTONE

The type section of the Loyalhanna (Siliceous or Mountain) limestone is in the Loyalhanna Gap southeast of Latrobe, in northeastern Westmoreland County. At this locality the formation is bluish-gray, non-fossiliferous, cross-bedded, and is made up of well rounded quartz grains embedded in calcareous cement. The quartz grains make up much more than half the rock. The calcareous matter is etched out during weathering so that the surfaces of outcrops are rough and pitted.

The top of the Loyalhanna limestone ranges from 1,010 to 1,300 feet below the base of the Pittsburgh coal in the six counties covered by this report, the difference in interval being due in part to the southeastward thickening of the strata and in part to post-Mississippian erosion. The interval is greatest in southwestern Greene County and decreases progressively northward into Washington County, although local differences are relatively great.

The Loyalhanna limestone crops out persistently in eastern Fayette and Westmoreland counties. Like the overlying Mauch Chunk formation, it thins northward.

POCONO FORMATION

The Pocono formation in general lithologic character comprises dark olive-green or gray shale and massive beds of sandstone, which are locally conglomeratic. The proportion of shale is generally larger and the sandstone members more lenticular and variable in the lower half, although the sandstone lentils thicken locally and make up most of the section. There is no sharp break in type of sedimentation at the base. The thickness of the Pocono formation has been reported by different workers as 300 to 2,000 feet in southwestern Pennsylvania, although the greater part of this apparent difference is due to the different horizons at which the base of the formation has been placed, and not to unequal sedimentation. In general the Pocono formation as defined above thickens eastward about 20 per cent within the area covered by this report, the average thickness being about 650 feet. In western Greene County, however, the formation thickens northwestward. In Allegheny and Butler counties, the post-Mississippian unconformity becomes lower and lower in the Pocono toward the north, and the remainder of the formation thickens southeastward. In this part of the area the Pocono is only about 400 feet thick.

BURGOON SANDSTONE

The topmost member of the Pocono formation, the Burgoon sandstone, takes its name from the type region along Burgoon Run at the Allegheny Front in Blair County. The top of the Burgoon sandstone lies 1,050 to 1,350 feet below the base of the Pittsburgh coal, and the interval increases progressively southward from a minimum in northern Washington County although it differs greatly within any

small part of the area. Its thickness is reported in well records as 100 to 350 feet, the maximum being in the northern part of the region where the member can not be distinguished from the overlying Pottsville formation and the lower strata of the Allegheny formation. The Burgoon member is generally a very hard yellowish-white or gray, unevenly-bedded sandstone, which is locally bisected or further subdivided by lentils of greenish-gray clayey shale between 10 and 80 feet in thickness.

In the area covered by this report the Burgoon sandstone does not crop out extensively, as shown by the geologic map (Pl. I). In Butler County it is exposed only in the valleys of Allegheny River and its tributary, Bear Creek, although it lies within easy reach of the drill over the northern third of the county. The member also crops out at several places along the axis of the Chestnut Ridge anticline in eastern Westmoreland and northern Fayette counties, and forms a nearly continuous crop along the axis and flanks of the Dulany anticline in Fayette County. Farther east it crops out all along the axis of the Laurel Hill anticline in both Westmoreland and Fayette counties.

In northern Butler County, at least as far south as a line which trends about S. 60°E. through Slippery Rock and Millerstown boroughs, the Burgoon sandstone yields copiously from coarse-grained permeable layers which are locally persistent at a given horizon. Representative wells are Nos. 107 and 108 of Marion Township, 117 adjacent to Allegheny Township, 125 and 126 of Slippery Rock Township, 127 of Cherry Township, 133 adjacent to Parker Township, 143 of Concord Township, 145 of Karns City Borough, and 157 of Donegal Township. The maximum known rate of draft is 150 gallons per minute, from well 125. Throughout this district the member lies somewhat below drainage level and retains water under moderate hydrostatic head, an area of artesian flow existing in the lowest points of the surface, as approximately outlined in the preceding discussion of the Homewood sandstone (p. 195). The permeability of the member is relatively constant in this part of the county. The reported figures for yield and drawdown of well 125 indicate a specific capacity of 30 gallons per minute for each foot of drawdown; in well 145, the specific capacity seems to be not less than 4 gallons a minute for each foot of drawdown. Obviously these figures are not exact, but they serve to indicate the permeability of the member.

In the Chestnut Ridge and Laurel Hill district the Burgoon sandstone supplies many hillside springs, some of which discharge more than 100 gallons per minute. Typical springs are 609 of North Union Township and 630 of Wharton Township, Fayette County. Drilled wells are few, although No. 445 of Fairfield Township, Westmoreland County, and 1103 of Wharton Township, Fayette County, are representative. The first of these flows by artesian pressure. Although the areas of potential artesian flow from the member can not be bounded from the data obtainable, they probably include the lower parts of the valley floors along the axis of the Ligonier-Ohiopyle syncline (Pl. I) and possibly also of the Latrobe-Uniontown syncline farther west. Moderate artesian head is likely but can only be proven by test drilling.

The character of the water from the Burgoon sandstone in northern Butler County is represented by analysis 108 (p. 72, and Fig. 33, p. 195). This is a moderately hard calcium bicarbonate water of high iron content, and is of only fair quality for most domestic and industrial uses. Such a water is also slightly corrosive and considerable difficulty has been experienced in the oil fields of northern Butler County from corrosion of casings where they pass through the member. In the Chestnut Ridge and Laurel Hill districts, on the other hand, the water from the springs and shallow drilled wells supplied by this member is only slightly concentrated and is of excellent quality for any ordinary purpose. Even where the member lies far below drainage level, its water is fresh and not highly concentrated, as is shown by analysis 445 (p. 78, and Fig. 33, p. 195). This is a moderately concentrated water that has been almost completely softened by exchange of bases (see pp. 85-86).

In the area south of Butler and west of Chestnut Ridge the Burgoon sandstone lies below drainage level and contains brackish water or very highly concentrated brine. Typical deep wells which find the member water-bearing are No. 1011 of Clinton Township, and 1012 of Buffalo Township, in Butler County; 1027 of Collier Township, in Allegheny County; No. 1060 of Upper Burrell Township, 1070 and 1071 of Hempfield Township, and 1074 of Unity Township, in Westmoreland County; also 1096 of Wayne Township, and 1098 and 1100 of Perry Township, in Greene County. The yield does not usually exceed one gallon per minute. In many parts of the region, however, as in the vicinity of Tarentum in eastern Allegheny County, the Burgoon sandstone is impermeable and fails to yield water. It is also not water-bearing over the greater part of Greene County.

PATTON SHALE

The Burgoon sandstone is generally underlain by 20 to 100 feet of red or dark greenish-gray shale. These beds crop out only in southern Fayette County (see Pl. I) at several places along the axis of the Dulany anticline and in the Youghiogheny River gaps through Chestnut Ridge and Laurel Hill. So far as is known they are not water-bearing. In the petroliferous districts of Butler County they are not water-bearing beneath deep cover.

SQUAW AND PAPOOSE SANDS

The Patton shale member is underlain by an extremely irregular and discontinuous sandstone which is known to the well driller as the Squaw sand. This sandstone may range from 10 to 100 feet thick within a small area, thickening and thinning inversely with the overlying shale member. Usually, however, it is about 50 feet thick and is moderately persistent in the western half of Washington and Greene counties. Farther eastward, however, it can not always be recognized.

The Squaw sand is closely underlain locally, especially in the northern part of the region, by the Papoose sand, a very irregular and discontinuous bed which elsewhere probably merges with the lower part of the Squaw by pinching out of the intervening shale. It is also probable that many drillers fail to take cognizance of the intervening shale when it is relatively thin.

The Squaw sand is not of consequence as a source of water on account of its very small and relatively inaccessible outcrops. Beneath the Allegheny Plateau the sand yields a very small amount of highly concentrated brine in some of the deep wells, as in No. 1011 of Clinton Township, Butler County and 1049 of Jefferson Township, Washington County. A sample of brine from this sand in well 1011 has a concentration of approximately 96,400 parts per million, which is equivalent to a 9½-per cent solution.

Beneath the Squaw sand, or the Papoose sand where present, lies 50 to 200 feet of soft, thinly-laminated, light-colored shale, which contrasts sharply with the Patton shale above in being lighter colored and less abundant in red members. Locally this member encloses many discontinuous bands of sandstone a few inches or a foot or two in thickness and is described by the well driller as "slate and shells." In northern Butler County and adjacent districts is is known as the "Big Shell." This arenaceous shale, which is correlated with the Orangeville shale member of the Cuyahoga formation of northwestern Pennsylvania, contains the oldest strata known to crop out within the region covered by this report.

MURRYSVILLE SAND

In general the top of a sandy zone occurs from 400 to 600 feet below the top of the Burgoon sandstone and 1,550 to 1,875 feet below the Pittsburgh coal. The section at a given locality may include from one to four sandy lentils, the resulting sandstone unit ranging from 5 to 170 feet in thickness, and, where it is thickest, nearly filling the interval to the underlying Hundred-foot sand, as in the Donaldson well of Robinson Township, Washington County.

The whole or a part of this sandy zone has been known in the northern part of the region as the Gas sand, Butler gas sand, Thirty-foot sand, and Butler Thirty-foot sand; in southern Allegheny, Westmoreland, and Greene counties as the Second Gas sand or Salt sand; and in northwestern Westmoreland County as the Murrysville sand.

The Murrysville sand does not crop out within the region except possibly in the Youghiogheny River gaps through Laurel Hill and Chestnut Ridge (see Pl. I).

In the area east of Chestnut Ridge the Murrysville sand is water-bearing at many localities, as in wells 445 of Fairfield Township, Westmoreland County and 1104 of Wharton Township, Fayette County. Generally the water is fresh and only slightly or moderately concentrated. The beds are, however, less permeable than the overlying Burgoon sandstone and hence are not a conspicuous source of water.

In the district west of Chestnut Ridge, however, the Murrysville sand lies far below drainage level and either is not water-bearing or contains salty water. In southwestern Butler County, Allegheny County, and norwestern Westmoreland County, the sand is coarse-grained or pebbly and relatively very permeable, and retains a highly concentrated brine under considerable head. Hence, it interferes seriously with the drilling of deep wells for gas or oil and requires very careful casing to effect a shut-off. So far as is known, the specific or ultimate capacity of a well reaching the Murrysville sand in

this region has never been determined but is far greater than the maximum rate of bailing. Farther south, in Washington and Greene counties, the Murrysville sand is not usually water-bearing. In Westmoreland County, however, it usually yields at the rate of 5 gallons per minute or less, the water rising in the well about 250 feet above the point it is encountered.

The character of the brine from the Murrysville sand is represented by analysis 1,011-B (p. 73). This brine contains 16,400 parts per million of dissolved solids and is wholly unfit for any ordinary use. In contrast with the brine from the overlying Squaw sand in the same well (analysis 1,011-A), this water contains only one-sixth as much material in solution and is relatively more concentrated in the sodium and bicarbonate radicles. This comparison is reflected in the driller's designation of the water from the Murrysville as fresh, sweet, or white.

DEVONIAN AND SILURIAN SYSTEMS

No rocks of Devonian or Silurian age crop out within the area covered by this report, but they have been penetrated by several deep test wells for oil and gas. The deepest three of these wells are: first, the R. A. Geary well, of the Peoples Natural Gas Co., located 4 miles northwest of McDonald in northern Washington County (1046, Fig. 39); second, the Lake No. 1 well of the Hope Natural Gas Co. near Fairmont, West Virginia; and third, two wells drilled by the Peoples Natural Gas Co. near McCance in Westmoreland County (1076, Fig. 40). The locations of these wells and the character of the strata penetrated are shown by the accompanying sketch (Fig. 34). Inasmuch as the strata thicken toward the southeast, the Geary well, although not the deepest, attains the lowest stratigraphic horizon. Hence, the record of this boring is presented herewith as a type for the oldest known rocks of southwestern Pennsylvania, the correlation being tentative and essentially that of I. C. White.[133]

[133] White, I. C., Note on a very deep well near McDonald, Pa.: Geol. Soc. Amer. Bull., vol. 24, pp. 275-282, 1913. Discussion of the records of some very deep wells in the Appalachian oil fields of Pennsylvania, Ohio, and West Virginia: West Virginia Geol. Survey, Barbour and Upshur Counties, pp. xxv-lxv, 1918.

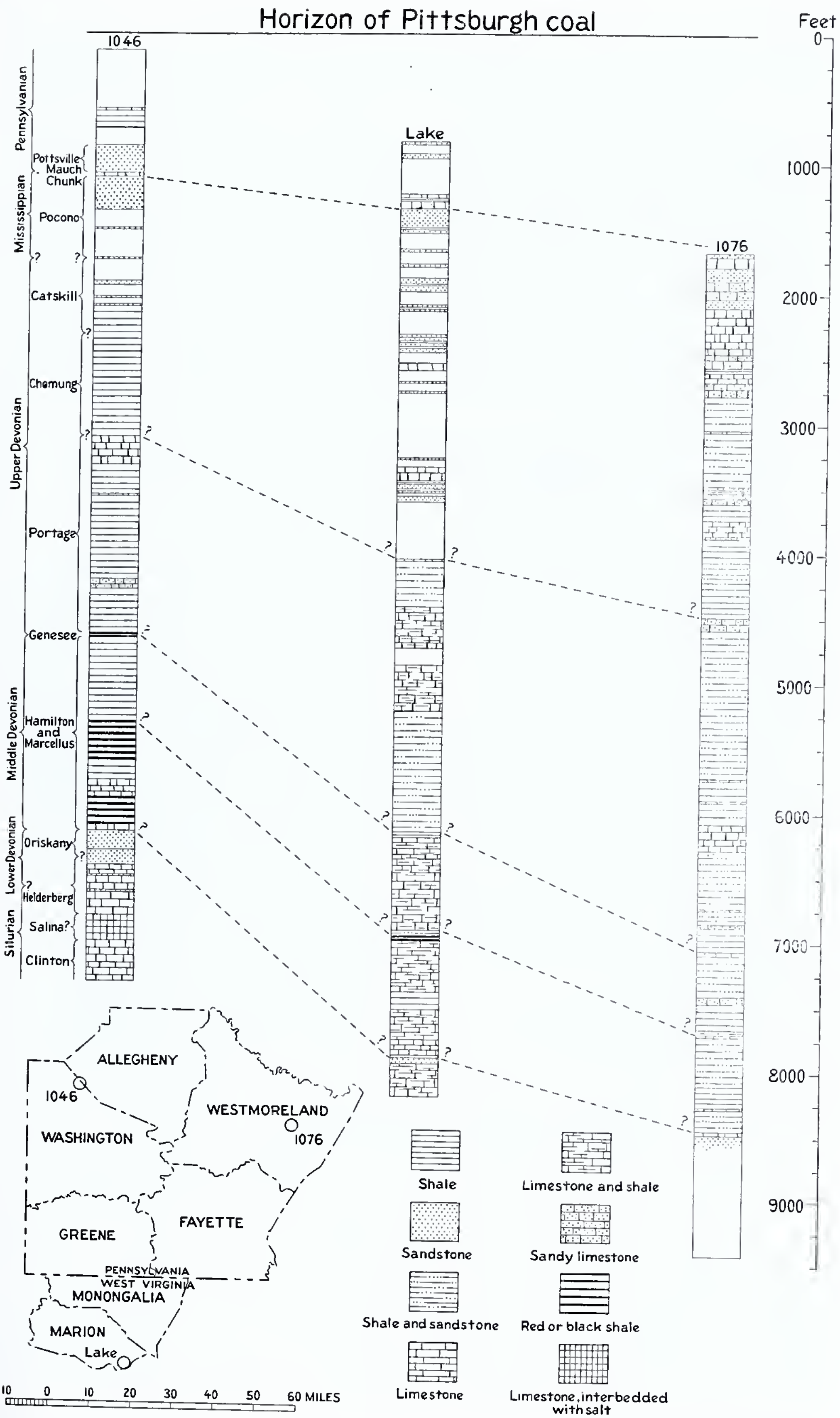


Figure 34.—Diagrammatic record of three deep wells in and near southwestern Pennsylvania.

Log of R. A. Geary well near McDonald

(No. 1046, Fig. 39 and p. 352.)

	Thickness	Depth
	Feet	Feet
Allegheny		
Ames limestone	20	450- 470
Shale	125	470- 595
Lower Kittanning (?) coal, water at base	5	595- 600
Pottsville		
Mauch Chunk		
Homewood and Connoquenessing sandstones (Salt sand)	216	734- 950
Shale (Pencil cave)	3	950- 953
Loyalhanna limestone (Big lime)	29	953- 982
Pocono		
Burgoon sandstone (Big Injun sand)	259	982-1,241
Squaw sand	14	1,378-1,392
Murrysville sand	12	1,610-1,622
Catskill and Chemung		
Hundred-foot sand	23	1,794-1,817
Nineveh (Thirty-foot sand)	15	1,910-1,925
Gordon stray or Boulder sand	3	1,968-1,971
White shale	1,019	1,971-2,990
Portage		
Limestone	220	2,990-3,210
White shale	230	3,210-3,440
Limestone	10	3,440-3,450
White shale	650	3,450-4,100
Sandy limestone	70	4,100-4,170
White shale	350	4,170-4,520
Genesee (?)		
Black shale	30	4,520-4,550
Hamilton and Marcellus		
White shale	650	4,550-5,200
Black shale	320	5,200-5,520
White shale	140	5,520-5,660
Limestone (Selinsgrove)	20	5,660-5,680
Dark-colored limestone	108	5,680-5,788
Black shale	220	5,788-6,008
Dark-colored limestone	15	6,008-6,023
Flint	22	6,023-6,045
Oriskany		
Gray sand, water in upper part	155	6,045-6,200
Brown sand, water-bearing from 6,260 to 6,270 feet Probably Lower Helderberg in part	115	6,200-6,315
Helderberg		
Dark-colored limestone	80	6,315-6,395
Sandy black flint	10	6,395-6,405
Dark-colored limestone	110	6,405-6,515
White sandstone, water-bearing from 6,520 to 6,530 feet	15	6,515-6,530
Dark-colored limestone	80	6,530-6,610
Gray limestone	90	6,610-6,700
Salina (?)		
Rock salt and sandy limestone (Contains six beds of salt 5 to 10 feet thick interspersed with limestone members 5 to 67 feet thick)	200	6,700-6,900
Clinton		
Limestone	25	6,900-6,925
Sandy limestone	323	6,925-7,248

Note. Peoples Natural Gas Co. No. 770. Diameter at top 13 inches, at bottom 4¼ inches.

So far as is known none of the Devonian or Silurian rocks contain fresh water and most of them are wholly dry. The Hundred-foot sand, which lies 380 to 650 feet below the top of the Burgoon sandstone and near the top of the Catskill formation, contains a very con-

centrated brine locally in the oil fields of Butler County but in many places it is not water-bearing. The character of the brine is represented by analysis 1004 (p. 73). In general none of the rocks below the Hundred-foot sand are water-bearing, although they yield a few gallons of brine a day in some of the oil and gas wells. In the Geary well the Upper and Middle Devonian rocks, which extend from 1,794 to 6,045 feet in depth, were not water-bearing. The sandstone beds of the Oriskany and Helderberg formations, however, yielded concentrated brine at 6,045, 6,260, and 6,520 feet. So far as is known these are the deepest three water-bearing formations reported in the literature. The character of the brine from the 6,260-foot aquifer is shown by the analysis on page 90. The Lake well did not encounter any water-bearing strata after a depth of 2,118 feet had been attained.[134] In the McCance wells water was encountered at depths of 60 and 530 feet, but none below.

SUMMARY DESCRIPTION BY COUNTIES

ALLEGHENY COUNTY

TOPOGRAPHY AND DRAINAGE

Allegheny County embraces the most complexly dissected portion of the Allegheny peneplain, remnants of which are now preserved in the flat hill tops and level ridge crests. These peneplain remnants attain a maximum elevation of 1,355 feet above sea level in the extreme northeastern corner of the county, thence decline gradually southward to a minimum of 1,200 to 1,280 feet above sea level. Submature drainageways of rounded contour dissect the peneplain to a well marked profile which is now 900 to 1,040 feet above sea level, a surface which is strikingly preserved in the Parker strath (See pages 23-25). This is a system of abandoned, tortuous, flat-floored river channels locally as much as 1½ miles wide, which follows the courses of the present major streams. The local relief between the two erosion surfaces is 250 to 300 feet. Below the Parker strath, the region is trenched by the youthful valleys of the present master stream, Ohio River, and its larger tributaries—Allegheny River from the east, and Monongahela and Youghiogheny rivers from the south and southeast. These streams have cut down to a minimum elevation of 650 feet above sea level and about 700 feet below the Allegheny peneplain. Back filling by glacial outwash and alluvium has built up flood plains as much as a mile or more in width along them at an elevation 700 to 850 feet above sea level. Although the extreme relief within Allegheny County is somewhat less than in the region to the north, the more youthful and relatively precipitous slopes induce an even greater local range in the conditions of ground water occurrence.

AREAL GEOLOGY

The consolidated sediments which crop out in Allegheny County range in age from uppermost Allegheny to middle Washington, the composite section being approximately 1,150 feet thick. The oldest rocks, the Freeport coal group of the upper part of the Allegheny

[134] Meinzer, O. E., The occurrence of ground water in the United States, with a discussion of principles: U. S. Geol. Survey Water-Supply Paper 489, p. 44, 1923.

formation, are exposed only in the northeastern part of the county in the valleys of Allegheny River and its tributaries Pine Creek, Wilson Run, and Bull Creek (See Pl. I). The youngest beds, the Middle Washington limestone horizon, cap the highest hills along the axis of the McMurry syncline in the south part of Bethel Township. The Conemaugh formation, by far the most extensive within the county, covers the entire area north of the Allegheny-Ohio valley with the exception of the few outcrops of Allegheny beds and scattered hilltop caps of the basal Monongahela in Franklin, Ross, and Reserve townships and in Allegheny Borough. It also occupies all but the ridge crests in the terrane between the Allegheny and Monongahela-Youghiogheny valleys, as well as south of the Ohio River and north of its tributary, Chartiers Creek and Robinson Run. The beds of the Monongahela formation are most extensive in the south-central portion of the county between Youghiogheny River and Robinson Run, although isolated areas occupy the topographic prominences northwestward to the boundary of the county and are preserved in the McMurray and Duquesne synclines to the northeast. The Washington formation covers detached areas in the Nineveh, McMurray, and Waynesburg synclines in the extreme southern part of the county. These sediments are overlain by unconsolidated alluvial and glacial materials which occupy extensive areas along the Ohio, Allegheny, Monongahela, and Youghiogheny rivers as well as Chartiers and Turtle creeks.

GEOLOGIC STRUCTURE

In Allegheny County the regional southwestward dip of the Carboniferous strata is wholly obscured by a number of sub-parallel folds which strike about N.30°E. In succession from the northwest, those which have been designated by geographic names are: West Middletown syncline; Crows Run anticline; the Sewickley and Mount Nebo synclines, which merge toward the south and thereby terminate the intervening Brush Creek anticline; Wildwood anticline; the Kellersburg anticline, which dies out southward against the flank of the Nineveh syncline; the McMurray syncline, the most westerly fold whose axis is persistent across the county; Amity anticline; Duquesne syncline; Murrysville anticline; Waynesburg syncline; and Bellevernon anticline. Of these, the most pronounced are the Kellersburg and Murrysville anticlines. In the western part of the county the axes of folding are indefinite and somewhat meandering and the dip of the flanks is variable. In the eastern part of the county, however, the linear aspect of the folds becomes more apparent and their depth relatively greater. These structural features are depicted on an accompanying map (Pl. I) by contours, drawn as though on the base of the Pittsburgh coal at the bottom of the Monongahela formation. The Carboniferous section showing only a very minor disconformity within the county, that at the top of the Conemaugh formation, the deformation of any given stratum is essentially the same as that of the index bed and may be read directly from the map. The relation between such structures and the occurrence of ground water has been discussed on pages 35-36.

GROUND WATER RESOURCES

General features

Those stratigraphic units which are sources of fresh water in Allegheny County are entered in the following table with citations to the pages on which their water-bearing properties are discussed at length. Of these, the outstanding beds are the unconsolidated alluvium, the sandstone strata, and the Uniontown and Benwood limestones of the Monongahela formation. In other portions of the section, ground water usually occurs in bedding plane conduits at the top or bottom of an impermeable stratum. The quality of the water obtainable from these sources is shown by the analyses which are tabulated on pages 70-75, and is treated further in the descriptions of the individual members. The known and potential areas of artesian flow have been noted on pages 64-69. The lower portion of the Allegheny formation and all underlying rocks within Allegheny County yield only saline water which is wholly unsuited for any ordinary use.

Sources of fresh water in Allegheny County

Formation and member	Pages of this report
Alluvium	103
Monongahela formation:	
Uniontown limestone	148
Benwood limestone	148
Fishpot limestone	152
Pittsburgh sandstone	154
Pittsburgh coal	155
Conemaugh formation:	
Pittsburgh limestones	158
Connellsville sandstone	159
Little Clarksburg coal and Clarksburg limestone	162
Morgantown sandstone	164
Birmingham shale	168
Duquesne coal	169
Ames limestone	169
"Pittsburgh Reds"	170
Saltsburg sandstone	171
Bakerstown coal	174
Cambridge limestone	174
Buffalo sandstone	176
Brush Creek coal	178
Mahoning sandstone	180
Allegheny formation:	
Upper Freeport coal and limestone	184
Butler sandstone	185
Freeport sandstone	186
Kittanning sandstone	189

The alluvium and glacial outwash of the Allegheny and Ohio valleys is the only source of ground-water supplies large enough for many industrial purposes. Adequate methods of constructing and finishing wells in these unconsolidated deposits have been discussed under that subject.

At many places southwest of Pittsburgh the beds above the Pittsburgh coal have been drained by mining and the underlying beds are shaly and not water-bearing so that it is impossible to obtain a supply of fresh ground water. Hence, household supplies in the rural districts are generally derived from rain catches and cisterns.

In the western part of the county in the vicinity of Imperial and

Midway the static level of the shallow fresh waters is below that of the deeper salty waters. At Imperial, salt water occurs in the Saltsburg sandstone at a depth of 128 feet and rises within 3 feet of the surface (see well 286, p. 216). At Midway, brackish water also occurs in the Saltsburg sandstone at a depth of 225 feet and rises within 65 feet of the surface (see wells 308 and 309, p. 228). Hence, where the oil and gas wells in these districts are inadequately cased the beds that contain fresh water may be flooded locally with brine. Throughout the county, any well which passes more than 50 or 100 feet below the level of the major streams is likely to encounter salt water which, in all valleys cut below 950 feet altitude, has a pressure head greater than that of the fresh waters. Hence, a strict technique in casing is essential to segregate the salt and fresh waters.

Municipal supplies

Supplies from the unconsolidated deposits. The unconsolidated alluvium of the Ohio, Allegheny, and Monongahela valleys has been developed for municipal needs by the city of Duquesne (No. 11, Fig. 35, and p. 112; also p. 214); by the Edgeworth Water Company (No. 4, Fig. 35 and p. 105; also p. 214), which supplies the boroughs of Edgeworth and Leetsdale; by the Ohio Valley Water Company (Nos. 6 and 7, Fig. 35 and p. 106; also p. 226), which supplies the boroughs of Bellevue, West View, Avalon, Ben Avon, and Emsworth on the north side of the Ohio River as well as the borough of McKees Rocks on the south bank; and, lastly, by Springdale Borough (No. 5, Fig. 35 and p. 110; also p. 244). Inasmuch as these developments have been described in full on the pages cited, there is no need to treat them further.

Natrona Water Company. The domestic water supply of Natrona is derived from a group of 22 springs along the crop of a shaly facies of the lower portion of the Mahoning sandstone (pages 178-183) in the north bluff of the Allegheny River trench (No. 251, Fig. 35 and p. 220). Each orifice has been opened by a bedding plane tunnel, tightly closed at the portal with brick masonry, also provided with a sand filter basin and a suitable gravity main leading to one of a series of collecting tanks. The longest tunnel is 60 feet. From the collecting tanks and reservoir, water is distributed by gravity to the residential section of the village, 75 to 100 feet below. The aggregate yield of the 22 spring openings is reported to be about 70 gallons per minute. It is reported further that the yield has diminished one-half during the past decade as a result of mining the Upper Freeport coal from beneath the aquifer at the eastern edge of the area. The metered consumption is approximately 35,000 gallons daily. Industrial and general municipal needs are met by pumping from Allegheny River. Both the surface water and ground water plants are operated by the Natrona Water Company, a subsidiary of the Pennsylvania Salt Manufacturing Company.

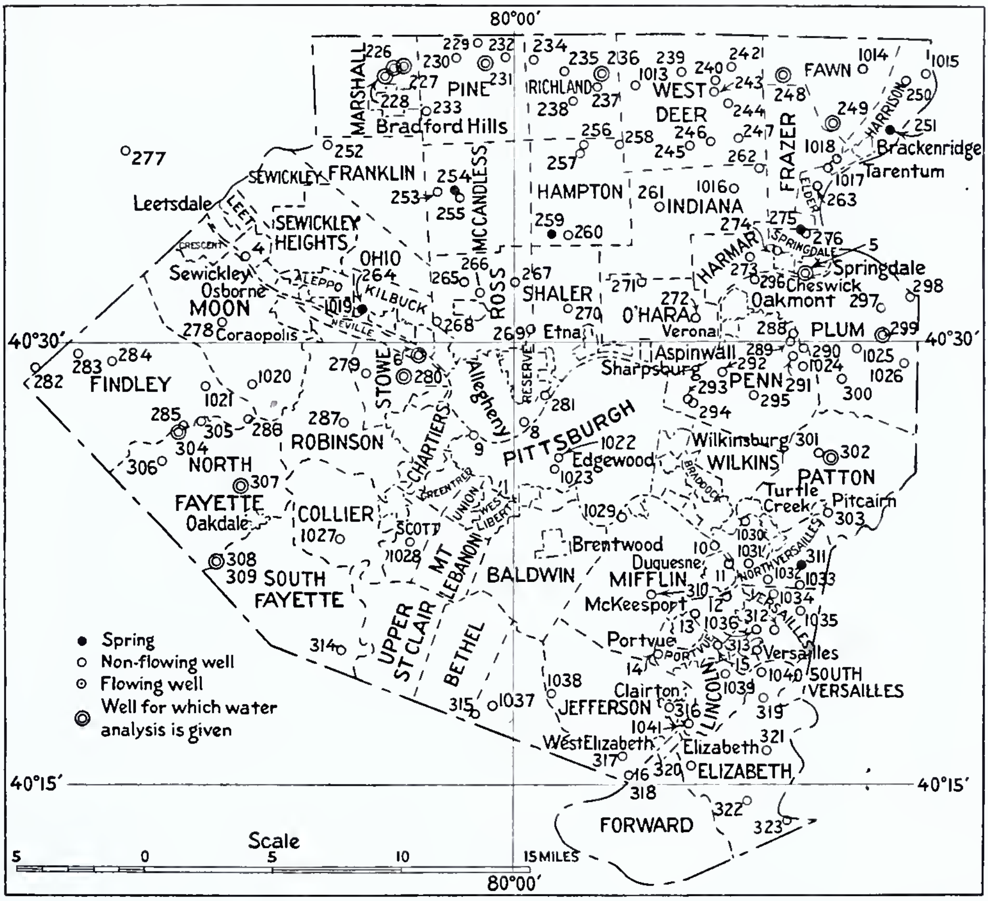


Figure 35. Map of Allegheny County showing location of wells and springs described in this report.

In the following tables of typical wells each right hand page is a continuation of the left hand page which it faces. Townships and boroughs are separated by horizontal lines for convenience in tracing the data for a given well from one page to the next.

TYPICAL WELLS AND SPRINGS IN ALLEGHENY COUNTY, PA.

No. on Fig. 35	Location: Nearest P. O.	Location: Distance and direction from P. O.	Owner or name	Topographic situation	Altitude above sea level	Depth of well	Diameter of well
	Allegheny Borough				Feet	Feet	Inches
8	Pittsburgh N. S.	1 mi. NE.	H. J. Heinz Co.	River plain	735	50-75±	30
281	Pittsburgh, N. S.	2¼ mi. NE.	Nichodemus	Valley	740	150	6¼
	Manchester		H. McClintock	----------	----------	----------	----------
	Baldwin Township						
			H. C. Burgman	----------	1,190	3,478	----------
			Jones & Laughlin Steel Co.	----------	1,099	2,353	----------
			William Devlin	----------	1,065	3,253	----------
			David Walker heirs	----------	1,225	3,496	----------
			E. M. Beech	----------	1,215	2,489	----------
			Davis heirs	----------	1,230	2,732	----------

Chief aquifer: Depth below surface	Chief aquifer: Character of material	Chief aquifer: Geologic horizon	Depth to which well is cased	Water level above + or below — surface	Method of lift	Capacity of pump	Rate of inflow	Use of water	Remarks
Feet			Feet	Feet		Gallons per minute	Gallons per minute		
Lower portion	Sand and gravel	Alluvium	To bottom	------------	Electric, turbine pump	400	400	Food products	Gravel-wall well with perforated casing, at factory, Ohio Street East, North Side, Pittsburgh.
Near base		Buffalo sandstone	------------	------------	Manual, force pump	1–2	Ample	Domestic	Located on Ohio Street East, close to cast boundary of borough.
1,400	Sandstone	Murrysville sand	------------	------------	None	------------	"Heavy"	None	
1,106	"Salt sand"	Clarion sandstone	------------	------------	None	------------	------------	None	Water-bearing formations cased off.
1,220 & 1,230	"Salt sand"	Pottsville formation							
1,400	"Big Injun sand"	Burgoon sandstone	------------	------------	------------	------------	1/50	------------	1½ bailers (45 gallons) water in 36 hours.
1,915	"Berea grit"	Murrysville sand	------------	------------	------------	------------	3/4	------------	1½ bailers (45 gallons) water per hour.
1,817	Sandstone	Murrysville sand	------------	------------	None	------------	------------	None	Formerly Stella D. Hays No. 2.
1,920 & ·1,960	Sandstone	Hundred-foot sand							
150	------------	Connellsville sandstone±	------------	------------	None	------------	------------	None	Cased off.
1,090	Sandstone	Homewood sandstone							
1,799	Sandstone	Murrysville sand							
1,892	Sandstone	Hundred-foot sand							
810	Coal	Upper Freeport	------------	------------	None	------------	5	None	Cased off.
------------	None	------------	------------	------------	------------	------------	------------	None	No water in Murrysville sand at depth 2,015 feet.
825	"Big Dunkard saud"	Mahoning sandstone	------------	------------	None	------------	Little	None	
1,185	"Salt sand"	Homewood sandstone							
1,938	Sandstone	Murrysville sand	------------	------------	------------	------------	Much	------------	Could not bail down.

No. on Fig. 35	Location: Nearest P. O.	Location: Distance and direction from P. O.	Owner or name	Topographic situation	Altitude above sea level	Depth of well	Diameter of well
					Feet	Feet	Inches
	Bethel Township						
			William McConkey No. 1	----------	1,095	2,556	----------
			Thomas Willis No. 1	----------	----------	2,649	----------
	Braddock Township						
			Wallace No. 1	----------	850	3,066	----------
	Clairton Borough						
316	Clairton	0	Carnegie Steel Co.	River terrace	920-960	75-125	6
	Collier Township						
1027	Rennerdale	1 mi. SE.	George B. Forsythe	Upland	1,150	2,800	10-6¼
			Hayes Crossing No. 1	----------	1,090	2,400	----------
			L. Shaffer No. 6	----------	----------	2,206	----------
			Allegheny County Home	----------	808	2,100	----------
	Crescent Township						
277	New Sheffield	0	J. H. Figley	Valley	950±	185	6¼
			Ezra P. Young No. 1	----------	705	1,641	----------

Chief aquifer: Depth below surface	Chief aquifer: Character of material	Chief aquifer: Geologic horizon	Depth to which well is cased	Water level above (+) or below (—) surface	Method of lift	Capacity of pump	Rate of inflow	Use of water	Remarks
Feet			Feet	Feet		Gallons per minute	Gallons per minute		
1,133	Top of sandstone	Homewood sandstone			None			None	Cased off.
1,755	Hard sandstone	Murrysville sand					"Very little"		
1,145	Sandstone	Kittanning sandstone			None			None	Water-bearing member cased off.
1,335	Sandstone	Homewood sandstone							
2,050	Sandstone	Murrysville sand							Could not bail down.
120	Base of blue shale	Bakerstown coal (?)			None			None	Cased off.
635	Sandstone	Homewood sandstone							Salt water; cased off.
Near base	Sandstone and shale	Morgantown sandstone			Manual, force pumps	1–3	Ample	Domestic, laborers dwellings	
1,265	Sandstone	Burgoon standstone			None			None	Peoples Natural Gas Co. No. 2024. Salt water.
1,890	Sandstone	Murrysville sand							Salt water.
525	Coal	Upper Kittanning coal			None			None	Water-bearing formations cased off.
700	Sandstone	Clarion sandstone (?)							
750	Sandstone	Homewood sandstone							
900	Sandstone	Kittanning or Clarion sandstone (?)			None			None	Salt water. Originally flowed due to gas pressure. Now abandoned.
50		Lower Pittsburgh limestone±			None			None	Fresh water. Cased off.
270	Coal	Harlem coal							Cased off.
290	Sandstone	Saltsburg sandstone							Cased off.
1,910	Sandstone	Hundred-foot sand							Salt water, produced with oil.
35	Sandy shale	Brush Creek coal ±		-25±	Force pump		1/10±	Domestic	Located in Beaver County.
160	Sandstone	Freeport sandstone±			None			None	Water-bearing formations cased off.
479	Sandstone	Pottsville formation							

No. on Fig. 35	Location: Nearest P. O.	Location: Distance and direction from P. O.	Owner or name	Topographic situation	Altitude above sea level	Depth of well	Diameter of well
					Feet	Feet	Inches
	Duquesne Borough						
11	Duquesne	0	Duquesne Borough	Stream plain	725±	50–65	10 & 12
	Edgeworth Borough						
4[a]	Sewickley	1 mi. NW.	Edgeworth Borough	Stream plain	675	35	10 & 12
	Elder Township						
263	Creighton	0	Nicklos	Valley	850	119	6
1017	Tarentum	¾ mi. SW.	Peterson	Valley	770	482	----------
	Elizabeth Township						
319	Boston	1 mi. SE.	Allegheny Country Club	Hillside	1,100±	505	10–8
320	Elizabeth	1¼ mi. SE.	Andrew Lucas	Hillside	1,050	217	----------
321	Frank	1¼ mi. W.	John Butler	Hillside	1,000	75	8–6
322	Blythedale	1¼ mi. W.	Joe Pierce	Valley	825	50	5-5/8
323	Blythedale	1¼ mi. S.	Pittsburgh Coal Co.	Valley	765	100	5-5/8
1040	Boston	¼ mi. E.	Donaldson	Valley	800	3,220	----------

[a] Analysis of water by U. S. Geological Survey.

Chief aquifer			Depth to which well is cased	Water level above (+) or below (—) surface	Method of lift	Capacity of pump	Rate of inflow	Use of water	Remarks
Depth below surface	Character of material	Geologic horizon							
Feet			Feet	Feet		Gallons per minute	Gallons per minute		
Near bottom	Sand and gravel	Alluvium	To bottom		Air lift			Municipal	Casings perforated at base. Aggregate yield in 1914, 1,900,000 gallons a day from 17 wells.
25	Sand and gravel	Alluvium	To bottom		Gas engine, suction pump			Municipal	Lower 8 feet of casing perforated with ¼ inch drilled holes 1½ inches center to center. Yield of 4 wells was 835 g. p. m. in 1926.
Near bottom	Shale	Butler sandstone±			Force pump		Ample		
365	Sandstone	Homewood sandstone					Unknown	Pumped for brine during the seventies	Now abandoned. Near by wells reported to have reached fresh water at a depth of 1,237 feet in the Murrysville sand.
55		Fishpot limestone±					Less than 1	Drinking	No water below to base of well which reaches Saltsburg sandstone. A second well found salt water at top Mahoning sandstone.
	Dry hole				None		None	Abandoned	Base of well reaches horizon of Lower Pittsburgh limestone, about 100 feet above Monongahela River.
45	White shale	Benwood limestone±			Manual, force pump	1–2	1±	Domestic	Well nearby 305 feet deep encounters no other water-bearing beds.
Near bottom	Gray shale	Close above Pittsbugh coal	To rock	–25	Manual, force pump	1–2	Ample	Domestic	Recovered yield a year after being drained by caving of mine roof.
83	Shale	Top of Morgantown sandstone	75	–27	Manual, force pump	1–2	2+	Domestic	Iron-bearing water at depth 65 and 69 feet; static level –21 feet.
740	Sandstone	Homewood sandstone			None			None	Salt water, cased off. Location of well uncertain.
1,560	Sandstone	Murrysville sand						None	Salt water.

No. on Fig. 35	Location: Nearest P. O.	Location: Distance and direction from P. O.	Owner or name	Topographic situation	Altitude above sea level	Depth of well	Diameter of well
					Feet	Feet	Inches
	Fawn Township						
248[a]	Russellton	3¼ mi. NE.	Wray's Garage	Valley	860	47	6¼
249[a]	Tarentum	1½ mi. N.	Frank Shearer	Valley	785	70	6¼
1014	Birdville	2 mi. NW.	Lawrence Bachman	Valley	1,120	2,570	----------
	Findley Township						
282	Clinton	3 mi. W.	Dr. J. M. Young	Stream head	1,050	155	6
283	Clinton	1¼ mi. W.	Elmer Adams	Stream head	1,150	100	6
284	Clinton	0	Miscellaneous	Upland	1,150–1,235	2,000+	10
285	Imperial	0	Arcade	Valley	960	68	6¼
286	Imperial	2¾ mi. E.	Briggs & Turivas	Valley	875	130	6
1021	Imperial	2 mi. NE.	A. J. Link	Hillside	1,160	2,209	10–6–5/8
			Meanor No. 1	----------	----------	2,077	----------

Chief aquifer			Depth to which well is cased	Water level above (+) or below (—) surface	Method of lift	Capacity of pump	Rate of inflow	Use of water	Remarks
Depth below surface	Character of material	Geologic horizon							
Feet			Feet	Feet		Gallons per minute	Gallons per minute		
Near bottom	Shale	Below Upper Freeport coal (?)	20	-8	Manual, force pump	2-3	Ample	Domestic, small garage	Millerstown community.
Near bottom	Base of sandstone	Freeport sandstone	------	-12	Automatic electric, suction pump	3	3+	Domestic	
1,560	Sandstone	Murrysville sand	------	------	None	------	------	------	T. W. Phillips Gas & Oil Co. Top water cased off at depth of 896 feet. Murrysville sand water could not be pumped off.
Near bottom	Sandy shale	"Pittsburgh Reds"	------	-40	Manual, force pump	1-2	2	Domestic, stock	Located in Beaver County.
70	Buff sandstone	Connellsville sandstone	------	-50	Not installed	------	------	Domestic	
95-185	Sandstone	Morgantown sandstone	------	-50±	None	------	2+	None	Conditions revealed in 5 oil wells; no fresh water below a depth of 217 feet.
65	------	Morgantown sandstone (?)	44	-5	Manual, force pump	1-3	2+	Household, stock	Salt water encountered at depth 30 feet is waste from near by oil well.
	Sandstone	------	------	-7	Electric, force pump	------	------	Steam crane boiler	Fresh water.
128	Gray sandstone	Saltsburg sandstone	------	-2½	------	------	------	------	Salty water.
35	Crevice in limestone	Lower Pittsburgh limestone	1,083	------	None	------	------	None	Fresh water.
575±	Base of limestone	Upper Freeport limestone±	------	-350	None	------	7½	None	Salt water.
870	Sandstone	Clarion and Homewood sandstones	------	-50±	None	------	------	None	Salt water. No water below this horizon. Could not bail down.
635	Sandstone	Homewood sandstone	------	------	None	------	------	None	Salt water; cased off.
785	Sandstone	Connoquenessing sandstone	------	------	------	------	------	------	
1,632	Sandstone	Hundred-foot sand	------	------	------	------	------	------	Hundred-foot sand dry in most wells.

No. on Fig. 35	Location: Nearest P. O.	Location: Distance and direction from P. O.	Owner or name	Topographic situation	Altitude above sea level	Depth of well	Diameter of well
					Feet	Feet	Inches
	Forward Township						
			Pittsburgh Coal Co.		870	2,561	------
	Franklin Township						
252	Warrendale	4¼ mi. SW.	F. M. Moats	Valley	890	115	6¼
			Wm. Weeley	------	1,170	2,047	------
	Hampton Township						
256	Gibsonia	1¾ mi. SE.	Mike Haberlein	Hillside	1,125	50	5
257	Gibsonia	2 mi. SE.	H. C. Fischer	Hillside	1,040	207	6¼
258	Gibsonia	2½ mi. SE.	Anti-Tuberculosis League	Stream head	1,150	97	6¼
259[b]	Allison Park	½ mi. W.	Allison Park Water Co.	Hillside	1,050	0	------
260	Allison Park	0	Allison Park Garage	Valley	960	60	------
	Harmar Township						
273	Cheswick	1¼ mi. W.	B. & L. E. R. R.	Terrace	865	250	4

[b] Flowing well or spring.

Chief aquifer			Depth to which well is cased	Water level above (+) or below (—) surface	Method of lift	Capacity of pump	Rate of inflow	Use of water	Remarks
Depth below surface	Character of material	Geologic horizon							
Feet			Feet	Feet		Gallons per minute	Gallons per minute		
644	Base of coal	Upper Freeport coal	------	------	None	------	1½	None	
1,195	------	Mauch Chunk formation (?)	------	------	None	------	1½	None	
105	Shale	Top of Mahoning sandstone	------	—60	Manual, force pump	1-2	Ample	Domestic	Duff City community.
788	Sandstone	Homewood sandstone	------	------	None	------	------	None	Salt water.
1,490	Sandstone	Murrysville sand	------	------	None	------	------	None	Salt water.
Near bottom	Shale	Bakerstown coal±	------	------	Force pump	------	------	Domestic	Upper Talleycavey community.
Near bottom	Gray sandstone	Mahoning sandstone	------	—55	Automatic electric, force pump	3¾	3¾+	Domestic	Contaminated by oil from near by oil well.
63	Sandstone	Saltsburg sandstone	23	—60	Force pump	5	5±	Domestic, stock	
0	Sandy shale	Top of Buffalo sandstone	------	------	Gas engine, suction pump	5	3±	Household	Spring. Three wells and this spring supply 30 families and a large greenhouse.
Near bottom	Sandy shale	Mahoning sandstone ±	------	------	Automatic electric, force pump	------	Ample	Domestic garage	
Near bottom		Freeport sandstone (?)	15	------	Manual, force pump	1-3	------	------	River Valley station, formerly Red Raven. Well abandoned.

No. on Fig. 35	Location: Nearest P. O.	Location: Distance and direction from P. O.	Owner or name	Topographic situation	Altitude above sea level	Depth of well	Diameter of well
					Feet	Feet	Inches
	Harrison Township						
250	Birdville	1½ mi. NE.	John Sarver	Terrace	1,165	115±	6¼
251[b]	Natrona	½ mi. N.	Natrona Water Co.	Hillside	900±	0	----------
1015	Freeport	1¾ mi. SW.	Sarah Boyd	Ridge crest	1,050	----------	----------
	Indiana Township						
261	Russellton	4¾ mi. SW.	Blue Run School	Valley	1,030	56	6
262	Russellton	1¼ mi. SE.	James Lewis	Valley	1,020	52	6
1016	Russellton	2 mi. S.	Carson	Hillside	1,140	----------	----------
	Jefferson Township						
16	Floreffe	½ mi. E.	Pittsburgh Plate Glass Co.	Stream plain	750	69-73	12
317	Floreffe	¾ mi. N.	Paul Vemrusa	Valley	800±	110	----------
318	Floreffe	½ mi. E.	Pittsburgh Plate Glass Co.	Stream plain	750	144	6
1038	Brueeton	1¼ mi. S.	Wm. Munhall	Valley	895	2,014	----------

Chief aquifer			Depth to which well is cased	Water level above (+) or below (—) surface	Method of lift	Capacity of pump	Rate of inflow	Use of water	Remarks
Depth below surface	Character of material	Geologic horizon							
Feet			Feet	Feet		Gallons per minute	Gallons per minute		
40	Shale	Below Saltsburg sandstone	----------	—25	Force pump	----------	1¼	Stock	Two wells yield 200 gallons an hour for dairy herd. Slump of roof above mines in Freeport coal has drained most wells 100 feet or more deep.
105	Shale	Top Mahoning sandstone	----------	----------	----------	----------	Small	----------	
0	Shale	Mahoning coal ±	----------	----------	None	----------	70	Municipal	Tabulated yield is aggregate of 22 spring openings.
1,555	Sandstone	Hundred-foot sand	----------	----------	None	----------	5+	None	T. W. Phillips Gas & Oil Co. Pumped steadily 4 days without lowering water.
Near bottom	Shale	Bakerstown coal ±	----------	----------	Manual, force pump	1-2	----------	Drinking	Schoolhouse not now in use; ½ mile south of Dorseyville.
Near bottom	Shale	Top Saltsburg sandstone±	----------	----------	Force pump	----------	----------	Domestic	
1,650±	Sandstone	Hundred-foot sand	----------	----------	Force pump	1¼	----------	None	T. W. Phillips Gas & Oil Co. Salt water, pumped with oil.
65±	Sand and gravel	Alluvium	To bottom	—40±	Force pump	60-80 each	80+	Producer gas plant	Four wells located at producer gas plant near well No. 318. Casing perforated with 500 drilled holes ½ inch diameter between 1 and 6 feet above the base.
Near bottom		Morgantown sandstone (?)	----------	----------	Manual, force pump	1-3	Ample	Domestic	
Near bottom	Sandstone lentil	"Pittsburgh Reds"	70±	—70	Force pump	----------	----------	Drinking, 2 boilers	Abandoned when steam power displaced by electricity.
653	Gray sandstone	Kittanning sandstone	----------	----------	None	----------	----------	None	Cased off. Located at Wallace station, B. & O. R. R.
815	White sandstone	Homewood sandstone							

No. on Fig. 35	Location: Nearest P. O.	Location: Distance and direction from P. O.	Owner or name	Topographic situation	Altitude above sea level	Depth of well	Diameter of well
					Feet	Feet	Inches
	Jefferson Township—Continued						
			Torrence heirs	----------	1,190	2,809	----------
			Louisa Wilson	----------	990	2,548	----------
	Floreffe	0	Joseph Walton	----------	780	3,367	----------
	Kilbuck Township						
264[1]	Dixmont	¼ mi. N.	Western Pennsylvania Hospital for the Insane	Hillside	1,025	0	----------
1019	Dixmont	¼ mi. W.	Dixmont No. 2	Valley	720±	1,802	----------
			E. M. Crawford No. 1	----------	985	2,016	----------
	Leet Township						
			R. R. Wilson No. 1	----------	----------	1,588	----------
	Lincoln Township						
1039	Boston	1 mi. W.	Bowman Bros.	----------	1,135	2,300	----------
1041	Elizabeth	1¾ mi. NE.	Thomas Caird No. 1	Valley	750	2,560	----------
			S. M. & T. H. Bowman	Valley	815	2,945	----------
			Frank Wolf No. 1	----------	1,110	4,512	----------

Chief aquifer: Depth below surface	Chief aquifer: Character of material	Chief aquifer: Geologic horizon	Depth to which well is cased	Water level above (+) or below (—) surface	Method of lift	Capacity of pump	Rate of inflow	Use of water	Remarks
Feet			Feet	Feet		Gallons per minute	Gallons per minute		
870	Sandstone	Freeport sandstone			None			None	Water cased off.
1,125	Sandstone	Homewood sandstone							
1,930	Sandstone	Murrysville sand					None		
49	Coal	Pittsburgh coal			None			None	Water cased off.
658	Sandstone	Mahoning sandstone							
965	Sandstone	Clarion sandstone							
638	Coal	Upper Kittanning (?)			None			None	Water cased off.
825	Sandstone	Homewood sandstone							
0	Jointed sandstone	Morgantown sandstone	0		Natural flow		1-5	Formerly drinking water	Spring. Abandoned in summer 1926 due to contamination.
480	Sandstone	Homewood sandstone			None			None	Salt water; cased off.
656	Coarse sandstone	Burgoon sandstone							
475	Coal	Upper Freeport (?) Coal			None			None	Water cased off.
1,472	Sandstone	Murrysville sand							
60	Sandstone	Mahoning sandstone			None			None	Water cased off.
220		Kittanning sandstone (?)							Salt water.
400	Sandstone	Homewood sandstone							No water.
630		Burgoon sandstone							Salt water.
577	Top of coal	Butler sandstone							Peoples Natural Gas Co. No. 1696. Salt water.
1,270	Sandstone	Burgoon sandstone							
1,585	Sandstone	Murrysville sand			None		2±	None	Wet hole at depth 1,600 feet.
210	Top of coal	Brush Creek coal (?)			None			None	
890	Sandstone	Pottsville formation							Salt water.
1,170	Sandstone	Burgoon sandstone							Salt water.
1,500	Sandstone	Murrysville sand							Salt water. Some near by wells have water in the Hundred-foot sand also.
50	Shale	Connellsville sandstone±			None		2½	None	Water-bearing formations cased off.
571	Coal	Upper Freeport coal					Little		
745	Coal	Middle Kittanning coal					1½		
1,870	Sandstone	Murrysville sand					2½		

No. on Fig. 35	Location: Nearest P. O.	Location: Distance and direction from P. O.	Owner or name	Topographic situation	Altitude above sea level	Depth of well	Diameter of well
					Feet	Feet	Inches
	McCandless Township						
253	Wexford	3 mi. S.	George Hamilton	Upland	1,225	140	6¼
254[b]	Perrysville	3¼ mi. N.	----------	Hillside	1,140	0	----------
255	Perrysville	3 mi. N.	Killians House Co.	Hilltop	1,175	95	6¼
			Roy Glenn	----------	----------	2,110	----------
			B. S. Redpath No. 2	----------	----------	----------	----------
	McKeesport Borough						
12	McKeesport	0	Firth-Stirling Steel Co.	Stream plain	735	65±	----------
13	McKeesport	0	Tube City Brewing Co.	Stream plain	760	61	----------
	Marshall Township						
226[a]	Warrendale	⅓ mi. W.	Allegheny County Industrial School	Hillside	1,100	82	6¼
227[a]	Warrendale	0	Warrendale Hotel	Valley	1,070	60	6¼
228[a]	Warrendale	¾ mi. SW.	Allegheny County Industrial School	Hillside	1,100	151	6¼
			J. B. Smith, No. 2	Valley	1,240	1,661	----------

[a] Analysis of water by U. S. Geological Survey.
[b] Flowing well or spring.

Chief aquifer: Depth below surface	Chief aquifer: Character of material	Chief aquifer: Geologic horizon	Depth to which well is cased	Water level above (+) or below (—) surface	Method of lift	Capacity of pump	Rate of inflow	Use of water	Remarks
Feet			Feet	Feet		Gallons per minute	Gallons per minute		
Near bottom	Shale	Birmingham shale	----------	----------	Force pump	1-3	Ample	Domestic	Some adjacent wells are oily or salty from oil well waste. New Ingomar community.
0	Jointed sandstone	Morgantown sandstone±	----------	----------	Natural flow	----------	10	Roadside trough	Spring.
85	Crevice in sandstone(?)	Morgantown sandstone(?)	----------	----------	Force pump	----------	Ample	Domestic	Water somewhat turbid with suspended clay particles.
370	Sandstone	Freeport sandstone	----------	----------	None	----------	----------	None	Salt water; cased off.
1,427	Sandstone	Murrysville sand	----------	----------	----------	----------	----------	----------	Salt water.
1,700±	Sandstone	Hundred-foot sand	----------	----------	Force pump	----------	See note	None	Salt water; 3,500 gal. a day declined in 10 years to 1,250 gal.
Near bottom	Sand and gravel	Alluvium	To bottom	----------	----------	----------	----------	Industrial	High iron content successfully removed by aeration.
Near bottom	Sand and gravel	Alluvium	To bottom	----------	Suction pump	----------	300±	Cooling	Now pumped 150-170 g. p. m. High iron content.
63	Friable sandstone	Saltsburg sandstone	28	—58	Gas engine, force pump	5	5+	Household	Cottage No. 18.
50±	Sandy shale	Saltsburg sandstone	40	—10	Gas engine, force pump	----------	5+	Household	Reported to be slightly salty from oil well waste.
115	Base of limestone	Cambridge limestone	22	—42	Automatic electric. force pump	3	3+	Household	Consumption 1,500± gallons a day.
1,560	Sandstone	Hundred-foot sand	----------	----------	Force pump	----------	5—	None	Original yield in 1894 was 7,500 gal. a day, salt water with oil; declined to 1,000 gal. in 1907. New wells in Brush Creek district yield 1,000-7,500 gal. a day of salt water and decline to 150-3,500 gal. in 7-13 years.

No. on Fig. 35	Location: Nearest P. O.	Location: Distance and direction from P. O.	Owner or name	Topographic situation	Altitude above sea level	Depth of well	Diameter of well
					Feet	Feet	Inches
	Mifflin Township						
10	Duquesne	1 mi. NW.	Union Railroad Co.	Stream plain	740	106	-----------
310	Dravosburg	½ mi. NW.	Adley Pierce	Upland	1,180	109	6
1029	Homestead	¾ mi. SW.	Pittsburgh-Bessemer Steel Co.	Valley	790	1,744	-----------
			Harry W. McGibbony	-----------	900	2,450	-----------
	Moon Township						
278	Coraopolis	2¾ mi. W.	Oscar H. Goss	Hilltop	1,200	112	6¼
1020	Imperial	3¼ mi. NE.	C. Heinline	Ridge crest	1,090	1,996	10–6⅝
			Vanderwort	-----------	895	1,934	-----------
	Neville Township						
6[a]	McKees Rocks	1½ mi. N.	Ohio Valley Water Co.	River bed	720	35–45	12

Chief aquifer: Depth below surface	Chief aquifer: Character of material	Chief aquifer: Geologic horizon	Depth to which well is cased	Water level above (+) or below (—) surface	Method of lift	Capacity of pump	Rate of inflow	Use of water	Remarks
Feet			Feet	Feet		Gallons per minute	Gallons per minute		
35–106	Sand and gravel	Alluvium	Temporary		Air lift				Three test wells on west bank Monongahela River, two on east bank; drilled through old slag dump. Too hard for boiler feed.
		Fishpot limestone±			Automatic electric, force pump		Ample	Household, grounds	A near by well went to abandoned mine on Pittsburgh coal without finding water; depth 221 feet.
127	Sandstone and shale	Saltsburg sandstone			None			None	Salt water.
587	White sandstone	Clarion sandstone							Salt water.
710	Sandstone	Connoquenessing sandstone							Salt water.
315	Sandstone	Saltsburg sandstone			None			None	
812	Sandstone	Homewood sandstone							
1,725	Sandstone	Murrysville sand							Water in Hundred-foot sand in a few wells.
90	Shaly sandstone	Connellsville sandstone			Manual, force pump	1–3	½	Domestic	
618		Freeport sandstone (?)	1,085		None			None	Peoples Natural Gas Co. No. 1124.
900	Sandstone	Homewood sandstone							
1,546	Sandstone	Hundred-foot sand					Little	None	Water found 12 feet above base of Hundred-foot sand.
Near bottom	Sand and gravel	Alluvium	To bottom	See text	Electric, centrifugal pumps	See notes		Municipal supply	Main channel gang of 28 wells yields 1,250 to 2,000 g. p. m. Back channel gang of 16 wells (No. 7) yields 1,250–1,650 g. p. m.

No. on Fig. 35	Location: Nearest P. O.	Location: Distance and direction from P. O.	Owner or name	Topographic situation	Altitude above sea level	Depth of well	Diameter of well
					Feet	Feet	Inches
	North Fayette Township						
304[a]	Imperial	0	Mrs. Martha Ross	Valley	980	48	6
305	Imperial	¾ mi. E.	Albert Weir	Hillside	990	126	6
306	Tyre	¾ mi. E.	J. Fullitare	Hillside	1,225	125±	5⅝
307[a]	Oakdale	1½ mi. NW.	Joe Mathews	Terrace	975	56	5⅝
308[a]	McDonald	1 mi. E.	South Penn Oil Co. No. 3	Valley	950	425	8-5⅝
309[a]	McDonald	1 mi. E.	South Penn Oil Co.	Valley	950	284	8-6
			A. W. Crooks No. 4	----------	1,220	2,171	----------
	North Versailles Township						
311[b]	East McKeesport	1¾ mi. SE.	Philip Naiser	Stream head	1,125	0	----------
1030	Turtle Creek	½ mi. S.	Kelly	Valley	800	2,155	----------
1031	East McKeesport	1 mi. SW.	Ella M. Lyle	Hillside	1,050	3,497	----------
1032	East McKeesport	1¾ mi. S.	Charles Mehaffey	Hilltop	1,220	2,113	----------
1033	East McKeesport	2 mi. SE.	G. C. Hoffman No. 1	Hillside	1,050±	3,201	----------

Chief aquifer: Depth below surface	Chief aquifer: Character of material	Chief aquifer: Geologic horizon	Depth to which well is cased	Water level above (+) or below (—) surface	Method of lift	Capacity of pump	Rate of inflow	Use of water	Remarks
Feet			Feet	Feet		Gallons per minute	Gallons per minute		
45	White sandstone	Morgantown sandstone		—7	Automatic electric, suction pump	3½	3½+	Domestic	
73	Shale	Birmingham shale			Force pump		½	Domestic	Well shot with dynamite to increase a small original yield.
Near bottom	Limestone	Pittsburgh limestones	63		Manual, force pump	1–3		Domestic	
48	"Blue" sand	Connellsville sandstone			Manual, force pump	1–3	Inadequate	Domestic	
75±	"Murphy" sand	Morgantown sandstone		—65	Air lift	40–50	50±	Condensers	Sturgeon compressing station
233	"Hurry-up" sand	Saltsburg sandstone							
392	"Little Dunkard" sand	Buffalo sandstone							
225	"Hurry up" sand	Saltsburg sandstone		—65	Air lift	40–50		Condensers	Sturgeon compression station.
1,035	"Salt" sand	Clarion and Homewood sandstones		—250±				None	Well not shown on Fig. 35.
2,020	Sandstone	Hundred-foot sand					Very little	None	
0	Fine sandstone	Connellsville sandstone			Natural flow		5–7		Spring. Formerly municipal supply for Wall Borough.
400	Gray sandstone	Mahoning sandstone			None		2±	None	Formerly W. F. Minteer No. 2.
1,830	Sandstone	Hundred-foot sand					1½±		
1,930	Sandstone	Murrysville sand			None			None	
2,089	Sandstone	Hundred-foot sand			None			None	
1,755	Sandstone	Murrysville sand			None			None	Peoples Natural Gas Co. No. 1125.
1,900	Sandstone	Hundred-foot sand							
2,185	Sandstone	Gordon sand							

No. on Fig. 35	Location: Nearest P. O.	Location: Distance and direction from P. O.	Owner or name	Topographic situation	Altitude above sea level	Depth of well	Diameter of well
					Feet	Feet	Inches
	O'Hara Township						
271	Sharpsburg	3 mi. NE.	Croft Campbell	Hillside	1,150	79	6
272	Sharpsburg	3¾ mi. NE.	O. P. Powers	Hillside	990	89	6
			McGrew, No. 1	Valley	850±	1,950	----------
	Ohio Township						
			Pinkerton	----------	----------	2,045	----------
b			Crawford	----------	----------	1,875	7⅝-5⅝
	Patton Township						
301	Pitcairn	2¾ mi. N.	Oliver Clark	Upland	1,200±	255	8-5⅝
302[a]	Pitcairn	2 mi. N.	S. N. Clark	Hillside	1,075	164	8-5⅝
203	Pitcairn	½ mi. E.	Roy Glenn	Hilltop	1,000	120	8-5⅝
b	Monroeville	1 mi. SE.	Munhall & Smithman	Valley	950±	----------	----------
			Oliver Elliott	----------	1,070	3,858	----------
			Dan Spangler	----------	1,065	2,511	----------

Chief aquifer			Depth to which well is cased	Water level above (+) or below (—) surface	Method of lift	Capacity of pump	Rate of inflow	Use of water	Remarks
Depth below surface	Character of material	Geologic horizon							
Feet			Feet	Feet		Gallons per minute	Gallons per minute		
Near bottom	Shale	Birmingham shale	--------	--------	Force pump	--------	Ample	Domestic	
Near bottom	Shale	Saltsburg sandstone	--------	--------	Force pump	--------	Ample	Domestic	
500	--------	Pottsville formation	--------	--------	None	--------	--------	None	Salt water.
1,475	Sandstone	Murrysville sand	--------	--------	--------	--------	--------	--------	Salt water.
525	Sandstone	Freeport sandstone	--------	--------	None	--------	--------	None	Salt water.
825	Sandstone	Homewood sandstone	--------	--------	--------	--------	--------	--------	Salt water.
1,324	Sandstone	Squaw sand(?)	--------	--------	--------	--------	--------	--------	Salt water.
1,295	Sandstone	Murrysville sand	--------	--------	None	--------	--------	None	Salt water flowed from pressure of natural gas when first drilled in 1888.
1,525 1,540 1,568	Sandstone	Hundred-foot sand	--------	--------	--------	--------	--------	--------	Salt water.
90	Sandstone	Connellsville sandstone	--------	--------	Manual, force pump	1-3	Very small	Domestic	Maximum yield reported 14 gallons a day. Monroeville community.
Near bottom	Sandstone	Morgantown sandstone	25	—65	Automatic electric, force pump	2	Ample	Domestic	
Near bottom		Morgantown sandstone (?)	--------	--------	Automatic electric, force pump	2	Ample	Domestic	
1,696 and 1,705	Coarse sandstone	Murrysville sand	--------	+	None	--------	--------	None	Flowed (by gas pressure?) 140 g. p. m. in 1891. "Fresh" water.
560	Top of coal	Lower Kittanning coal	--------	--------	None	--------	--------	None	Peoples Natural Gas Co. No. 1024
1,700	Sandstone	Murrysville sand							
925	White sandstone	Homewood sandstone	--------	--------	None	--------	--------	None	Philadelphia Gas Co. No. 454
1,777	Sandstone	Murrysville sand							

No. on Fig. 35	Location		Owner or name	Topographic situation	Altitude above sea level	Depth of well	Diameter of well
	Nearest P. O.	Distance and direction from P. O.					
					Feet	Feet	Inches
	Penn Township						
288	North Bessemer	⅓ mi. N.	Newfield By-products Coal Co.	Valley	890	300	6
289	North Bessemer	½ mi. NW.	Newfield By-products Coal Co.	Hillside	1,050±	500±	6
290[b]	North Bessemer	¼ mi. SE.	B. & L. E. R. R.	Valley	890	95	12
291	North Bessemer	¼ mi. S.	B. & L. E. R. R.	Hillside	1,000	258	12
292	Verona	1⅞ mi. S.	Westmoreland Country Club	Terrace	970	350	8
293	Verona	3 mi. SW.	Rudolph Thon	Hillside	1,130	40	5⅝
294	Verona	3¼ mi. SW.	L. E. Osborne	Hillside	1,100	85	5⅝
295	Verona	2½ mi. SE.	P. Massarelli	Hilltop	1,260	492	6
1024	North Bessemer	¾ mi. S.	J. W. Jackson No. 2	Valley	960	----------	----------
			Alex. Duff	----------	1,110	----------	----------
			B. F. Herr No. 1	----------	1,070	2,367	----------
			Pahlman heirs, No. 1	----------	1,120	2,564	----------
			Walburga Burkhard	----------	1,190	2,470	----------

Chief aquifer			Depth to which well is cased	Water level above (+) or below (−) surface	Method of lift	Capacity of pump	Rate of inflow	Use of water	Remarks
Depth below surface	Character of material	Geologic horizon							
Feet			Feet	Feet		Gallons per minute	Gallons per minute		
200±	Coarse sandstone	Mahoning sandstone	500	−50	None	------------	100±	None	Water cased off to make conduit to mine for electric cables.
250	Red shale	Top of Saltsburg sandstone	250+	----------	None	------------	Very small	None	Drilled for domestic supply at miner's dwelling. No water found below depth of 250 feet.
90	Sandstone	Saltsburg sandstone	18	+ Slight	Force pump	------------	108	Formerly for locomotive boilers	North Bessemer station; well in Plum Creek valley. Slight flow when drilled in 1906.
30	Sandstone	Morgantown sandstone	----------	----------	None	------------	1½	None	North Bessemer roundhouse. Inadequate and never used.
250±	Sandstone	Mahoning sandstone	----------	−160	Electric, force pump	------------	13	Domestic	
33	Base of limestone	Lower Pittsburgh limestone	----------	−20	Automatic electric suction pump	------------	Ample	Domestic	
78	Base of sandstone	Connellsville sandstone	----------	----------	Automatic electric force pump	2±	3	Domestic	
250	Gray sandstone	Connellsville sandstone	120	−200	Automatic electric force pump	2	Ample	Domestic	No water-bearing beds below Connellsville sandstone.
1,672	Sandstone	Murrysville sand	----------	----------	None	------------	------------	None	T. W. Phillips Gas & Oil Co.
1,040	Sandstone	Homewood sandstone	----------	----------	None	------------	3	None	Salt water.
1,888	Sandstone	Murrysville sand							
2,080	Sandstone	Hundred-foot sand	----------	----------	----------	------------	------------	------------	Salt water.
85	----------------	Morgantown sandstone(?)	----------	----------	None	------------	------------	None	Fresh water.
375	----------------	Saltsburg sandstone(?)	----------	----------	----------	------------	------------	------------	Fresh water.
1,790	Sandstone	Murrysville sand							
560	Coal	Upper Freeport	----------	----------	None	------------	2½	None	
723	Coal	Middle Kittanning							
1,790	Sandstone	Murrysville sand							
1,942 and 1,977	Sandstone	Hundred-foot sand							
1,820	Sandstone	Murrysville sand	----------	−1,200	None	------------	Very small	None	Water appeared 6 days after drilling; filled well 600 feet in 42 days.

No. on Fig. 35	Location: Nearest P. O.	Location: Distance and direction from P. O.	Owner or name	Topographic situation	Altitude above sea level	Depth of well	Diameter of well
					Feet	Feet	Inches
	Pine Township						
229	Mars	2¼ mi. S.	Treesdale Farms, No. 1	Hillside	1,260	130	6¼
230	Warrendale	2¼ ml. E.	Meredith Marshall	Hillside	1,180	270	6¼
231[a] [t]	Mars	3 ml. S.	E. V. Babcock	Hillside	1,200	135	8
232	Gibsonia	2¾ mi. NW.	Mrs. Cryder	Upland	1,300	137	4¾
233	Wexford	¾ mi. NW.	Miscellaneous	Upland	1,275	75-135	6¼
	Pittsburgh Borough						
9	Pittsburgh (Mount Washington Station)	1½ ml. NW.	Pennsylvania Drilling Co.	Stream plain	720	67	----------
1022	Pittsburgh	----------	Morehead & Co.	Valley	730	2,007	----------
1023	Pittsburgh	----------	American Iron and Steel Works, No. 1	Stream plain	735	3,000	----------
			Boyd's Hill	Hillside	865	2,360	----------

Chief aquifer			Depth to which well is cased	Water level above (+) or below (—) surface	Method of lift	Capacity of pump	Rate of inflow	Use of water	Remarks
Depth below surface	Character of material	Geologic horizon							
Feet			Feet	Feet		Gallons per minute	Gallons per minute		
114	White sandstone	Saltsburg sandstone		—90	Windmill, force pump	3½	3½+	Domestic, stock	
55		Ames limestone±	40		None		1±	None	
80(?)	Sandstone	Saltsburg sandstone	0	—Slight	Electric, force pump	40	40+	Domestic, stock, fruit farm	Flow 3 g. p. m.; specific capacity about 10 g. p. m. for each foot of drawdown. Abandoned oil well re-drilled and plugged 135 feet below the surface.
119	Sandstone	Morgantown sandstone		—119	Force pump	1-3	Ample	Domestic	
Near bottom	Sandstone and shale	Birmingham shale	23	—35	Force pumps	1-3	Ample	Domestic	Sunnyhills Manor plan of lots. Ground water occurrence erratic.
Near bottom	Sand and gravel	Alluvium	67		Force pump		Large	Shop service, drinking	Perforated casing.
51	Sandstone	Saltsburg sandstone (upper)			None			None	Located on Second Ave. east of Brady Street.
200	White sandstone	Buffalo sandstone							Salt water.
380	Sandy shale	Freeport sandstone							Salt water.
480	Blue sandstone	Worthington sandstone±							Salt water.
550	Fine white sandstone	Kittanning sandstone							Salt water.
1,530	Sandy shale	Murrysville sand(?)					Large		Salt water.
360	Sandy shale	Freeport sandstone ±			None			None	Salt water. Located east of 26th St., South Side.
480	Sandy shale	Worthington sandstone							Salt water.
510	Sandy shale	Kittanning sandstone							Salt water.
1,525	Sandstone	Murrysville sand					Large		Salt water.
2,400	Sandy shale	Elizabeth sand±							Salt water.
2,625	Sandy shale	Warren sand(?)					5±(?)		
86	Coal	Berlin coal ±			None			None	Fresh water. Located at south end Boyd's Hill near Monongahela River.
587	Sandstone and shale	Worthington sandstone							Salt water.
729	Sandstone	Homewood sandstone							Salt water.
1,590	Sandstone	Murrysville sand							Salt water.

No. on Fig. 35	Location: Nearest P. O.	Location: Distance and direction from P. O.	Owner or name	Topographic situation	Altitude above sea level	Depth of well	Diameter of well
					Feet	Feet	Inches
	Pittsburgh, N. S.	----------	Bothwell	Terrace	900±	175	----------
			Carl Swartz No. 4	----------	1,100	1,995	----------
			Carl Swartz No. 1	----------	1,090	2,375	----------
	Plum Township						
296	Oakmont	1½ mi. NE.	B. & L. E. R. R.	Terrace	900	101	6
297	Renton	1¼ mi. N.	----------	Ridge crest	1,220	60	6
298	Renton	2 mi. NE.	Keibler	Hillside	900	72	6
299[a]	Renton	0	Union Collieries Coal Co.	Hillside	1,180	132	6
300	North Bessemer	2 mi. SE.	Center Beach Co.	Valley	1,040	50	8
1025	Renton	1¼ mi. W.	A. J. Patterson	Hillside	1,180	----------	----------
1026	Renton	1 mi. SE.	R. Jackson No. 6	Ridge crest	1,240	----------	----------
			J. C. Dougherty	----------	1,140	2,413	----------

Chief aquifer: Depth below surface	Chief aquifer: Character of material	Chief aquifer: Geologic horizon	Depth to which well is cased	Water level above (+) or below (—) surface	Method of lift	Capacity of pump	Rate inflow	Use of water	Remarks
Feet			Feet	Feet		Gallons per minute	Gallons per minute		
Near bottom		Mahoning sandstone (?)					2±	Boiler feed at drilling rig	
370	Sandstone	Saltsburg sandstone			None			None	Cased off.
740	Coal	Upper Kittanning (?)			None		2½	None	Cased off.
900	Sandstone	Homewood sandstone					Large		Could not bail down.
Near bottom		Brush Creek coal ± ?	20		Force pump		Ample	Drinking	Blacks Run station.
Near bottom	Sandy black shale	Connellsville sandstone			Manual, force pump	1-3	Ample	Domestic	
45	Sandstone lentil	Saltsburg sandstone		—30 to 35			Ample	Domestic	Drennen community.
100 and 120	Sandstone and red shale	Above Morgantown sandstone			Electric, force pump	10	10+	Domestic	Well at superintendent's house; 60 to 70 wells supply community; depth 75-205 feet, yield 0-17 g. p. m.
35	Base of limestone	Clarksburg limestone		—15	Electric, centrifugal pump	100		Swimming pool	
1,750±	Sandstone	Murrysville sand	2,049		None			None	T. W. Phillips Gas & Oil Co. Water cased off; could not be bailed down.
125±		Morgantown sandstone						Boiler	T. W. Phillips Gas & Oil Co.
630	Coal	Upper Freeport							
1,890	Sandstone	Murrysville sand							Salt water.
955		Homewood sandstone (?)			None		1½	None	Peoples Natural Gas Co. No. 945.

No. on Fig. 35	Location: Nearest P. O.	Location: Distance and direction from P. O.	Owner or name	Topographic situation	Altitude above sea level	Depth of well	Diameter of well
					Feet	Feet	Inches
	Murrysville	3 mi. NW.	R. G. Sharp	----------	1,160	2,447	----------
			H. H. Brunner	----------	950	3,800	----------
	Portvue Township						
14	Glassport	0	United States Glass Co.	Stream plain	740±	74	10
15	McKeesport	1¼ mi. SE.	McKeesport Tin Plate Co.	Stream plain	740	65±	----------
			Pittsburgh Steel Foundry Co. No. 1	Stream plain	745	----------	----------

Chief aquifer			Depth to which well is cased	Water level above (+) or below (—) surface	Method of lift	Capacity of pump	Rate of inflow	Use of water	Remarks
Depth below surface	Character of material	Geologic horizon							
Feet			Feet	Feet		Gallons per minute	Gallons per minute		
600	Coal	Upper Freeport	-----	-----	None	-----	-----	None	Philadelphia Gas Co. No. 474.
765	Coal	Middle Kittanning	-----	-----	-----	-----	-----	-----	
815	Shale	Vanport limestone ±	-----	-----	-----	-----	-----	-----	
1,843	Sandstone	Murrysville sand	-----	-----	-----	-----	-----	-----	
1,948	Sandstone	Hundred-foot sand							
275	Dense white sandstone	Mahoning sandstone	-----	-----	None	-----	-----	None	
1,670	Sandstone	Murrysville sand							
1,874	Sandstone	Murrysville sand							
68	Sand and gravel	Alluvium	74	-----	Force pump	-----	25+	Drinking, industrial	Casing perforated with 450 drilled holes ½ inch diameter from 68 to 73 feet deep.
60±	Sand and gravel	Alluvium	To bottom	-----	Suction pump	-----	-----	Industrial	Group of 7 or 8 wells about 30 feet apart; aggregate yield reported 1,000± g. p. m.; perforated casings.
500	Sandstone	Freeport sandstone	-----	-----	None	-----	-----	None	Cased off.
547	Sandstone	Worthington sandstone					Large		
883	Sandstone	Burgoon sandstone (?)							
1,650	Sandstone	Murrysville sand							
1,890	Sandstone	Fifty-foot sand							

No. on Fig. 35	Location: Nearest P. O.	Location: Distance and direction from P. O.	Owner or name	Topographic situation	Altitude above sea level	Depth of well	Diameter of well
					Feet	Feet	Inches
	Richland Township						
234	Gibsonia	2¼ mi. NW.	John Schaik	Upland	1,300	142	5⅝
235	Bakerstown	1½ mi. W.	St. Barnabas Home	Upland	1,270	300	6¼
			St. Barnabas Home	Hillside	1,200±	155–315	6¼
236[a]	Bakerstown	0	M. & M. Filling Station	Valley	1,075	72	6¼
237	Bakerstown	½ mi. S.	Robert Garaux	Hillside	1,190	80	----------
238	Gibsonia	¾ mi. NE.	----------	Hilltop	1,220	170	6¼
	Robinson Township						
287	Moon Run	¼ mi. N.	Pittsburgh Coal Co.	Valley	1,080±	150	8
	Ross Township						
265	Perrysville	½ mi. S.	----------	Hilltop	1,200	100	6¼
266	Westview	¾ mi. NE.	William Best	Terrace	1,170	100	6¼
267	Westview	2 mi. NE.	Abel Wiggles	Upland	1,125±	75	6¼
268	Bellevue	1 mi. N.	John Collins	Valley	940	50	6¼
269	Millvale	1¾ mi NW.	Roy Smith	Valley	850	50	6¼
			Fuller No. 1	----------	----------	1,743	----------
			George Orth No. 4	----------	920	1,956	----------

Chief aquifer			Depth to which well is cased	Water level above (+) or below (—) surface	Method of lift	Capacity of pump	Rate of inflow	Use of water	Remarks
Depth below surface	Character of material	Geologic horizon							
Feet			Feet	Feet		Gallons per minute	Gallons per minute		
Near bottom	Base of limestone	Ames limestone (?)	52	—80	Manual, force pump	1-3	2½	Domestic	
Near bottom	White sandstone	Buffalo sandstone ±	----	----	Force pump	50	See note	Household	Well No. 1 drilled in 1918; failed after 6 months' use with pump capacity 50 g. p. m. used as stand by in 1926.
	White sandstone	Buffalo sandstone ±	----	----	Force pump	----	----	Household	Wells Nos. 2, 3, 4 and 5; yield 3-6½ g. p. m. each; decline in yield about 30 per cent in 3 years.
50±	White sandstone	Buffalo sandstone	40±	----	Manual, force pump	1-3	Ample	Drinking water; service station	Iron-bearing water in overlying Bakerstown coal is cased off.
Near bottom	Shale	"Pittsburgh Reds"	----	----	Force pump	----	Ample	Domestic	
140	Sandstone	Saltsburg sandstone	62	----	Automatic electric, force pump	3½	3±	Domestic	Fairview plan of lots.
Near bottom	Red shale	Little Pittsburgh coal ±	----	—15±	Force pump	20	Small	Domestic	Group of 7 wells: 5 are 150 feet deep; 2 are 70 feet deep.
90	Sandstone	Morgantown sandstone	20	----	Force pump	1-3	----	Domestic	Drilled for Mr. Pinkerton, contractor, on new plan of lots. Owner not known.
90	Sandy shale	Birmingham shale	----	—60	Force pump	----	Ample	Domestic	Laurel Gardens plan of lots.
75	Shale	"Pittsburgh Reds"	22½	—45	Force pump	1-3	1—	Domestic	
40	Sandstone and shale	Bakerstown coal ±	20	—15	Force pump	3±	Ample	Domestic	
40	Shale	Brush Creek coal ±	16	----	Manual, force pump	1-3	Ample	Small garage	Park Auto and Machine Co.
1,400	Sandstone	Murrysville sand	----	----	None	----	----	None	Salt water.
200	----	Mahoning sandstone ±	----	----	None	----	----	None	Fresh water.

No. on Fig. 35	Location: Nearest P. O.	Location: Distance and direction from P. O.	Owner or name	Topographic situation	Altitude above sea level	Depth of well	Diameter of well
					Feet	Feet	Inches
	Scott Township						
1028			Henry Daub	Ridge crest	1,100	2,690	16-5-3/16
			S. S. Nixon No. 1	----------	940±	2,165(?)	----------
			John Schmitt No. 1	----------	890	2,169	----------
	Sewickley Township						
			Thomas Martin No. 1	----------	990	2,100	----------
	Shaler Township						
270	Glenshaw	$\frac{3}{4}$ mi. S.	Elizabeth Shepfer	Ridge crest	1,070	60	6
	Snowden Township						
315	Library	0	Pittsburgh Coal Co.	Valley	1,000	56-90	$5\frac{5}{8}$
1037	Library	$\frac{3}{4}$ mi. E.	C. H. Handel	Valley	1,025	2,578	10-4
			Cochran No. 1		965	2,348	----------
	South Fayette Township						
314	Lawrence	$1\frac{3}{4}$ mi. N.	J. M. Magee, deceased	Ridge crest	1,000±	206	----------
			J. M. Magee, deceased	Ridge crest	1,020	130	----------
			H. Sterling, No. 3	----------	1,270	2,480+	----------

Chief aquifer			Depth to which well is cased	Water level above (+) or below (—) surface	Method of lift	Capacity of pump	Rate of inflow	Use of water	Remarks
Depth below surface	Character of material	Geologic horizon							
Feet			Feet	Feet		Gallons per minute	Gallons per minute		
2,200	Shale	Upper Devonian	796	----------	None	----------	----------	None	Salt water. Peoples Natural Gas Co. No. 1075.
1,130	Base of sandstone	Homewood sandstone	----------	----------	None	----------	$\frac{3}{4}$	None	Cased off.
450	----------	Saltsburg sandstone±	----------	----------	None	----------	----------	None	Salt water.
620	Dark sandstone	Saltsburg sandstone	----------	----------	None	----------	1±	None	Water-bearing members cased off.
835	Coal	Upper Freeport	----------	----------	----------	----------	----------	----------	
975	Coal	Upper (?) Kittanning	----------	----------	----------	----------	----------	----------	
1,180	Sandstone	Clarion and Homewood sandstones	----------	----------	----------	----------	$2\frac{1}{2}$	----------	
2,097	Sandstone	Murrysville sand	----------	----------	----------	----------	4	----------	
Near bottom	Shale	"Pittsburgh Reds"	----------	----------	----------	----------	----------	Domestic	
Near bottom	Sandy shale	Pittsburgh sandstone(?)	35±	24	Electric, suction pump	----------	25±	Domestic, machine shops	Machine shops and Montour No. 10 mine. Four wells of which two have aggregate yield 60,000 gallons per day.
515	Sandstone	Saltsburg sandstone	2,591	----------	None	----------	----------	None	Peoples Natural Gas Co. No. 1144.
1,103	Sandstone	Homewood sandstone	----------	----------	----------	----------	----------	----------	
352	Sandstone	Saltsburg sandstone	----------	----------	None	----------	----------	None	Philadelphia Gas Co. No. 96. Salt water.
206	Coal	Pittsburgh coal	----------	----------	----------	----------	----------	----------	Drilled as gas well; drowned out by water.
79	----------	Uniontown limestone(?)	----------	----------	----------	----------	$\frac{1}{3}$	----------	Shot with dynamite and lost water.
1,120	Sandstone	Clarion sandstone	----------	----------	----------	----------	----------	None	Salt water.

No. on Fig. 35	Location: Nearest P. O.	Location: Distance and direction from P. O.	Owner or name	Topographic situation	Altitude above sea level	Depth of well	Diameter of well
					Feet	Feet	Inches
	Springdale Township and Borough						
5[a]	Springdale	0	Springdale Borough	Stream plain	753	66½	12
274	Cheswick	½ mi. N.		Hilltop	950±	73 and 140	6¼
275[b]	Springdale	1½ mi. N.	Springdale Borough	Stream head	975±	0	------------
276	Springdale	1½ mi. N.	Springdale Borough	Valley	950±	143–213	6¼
	Stowe Township						
279	Moon Run	2¼ mi. NE.	Dockweiler	Hillside	1,125	71	6
280[a]	McKees Rocks	1½ mi. NW.	Dr. Hanover	Terrace	1,085	83	6
			Nichol No. 3	------------	1,100	2,205	------------
			Wm. Skiles heirs No. 4	------------	1,175	1,742	------------
	Swissvale Borough						
			J. W. Milligan Estate	------------	1,075	2,404	------------

Chief aquifer: Depth below surface	Chief aquifer: Character of material	Chief aquifer: Geologic horizon	Depth to which well is cased	Water level above (+) or below (—) surface	Method of lift	Capacity of pump	Rate of inflow	Use of water	Remarks
Feet			Feet	Feet		Gallons per minute	Gallons per minute		
40	Gravel and sand	Alluvium	66	—30	Electric, force pump	350	350+	Municipal supply	No. 3 well; Cook strainer near bottom. Specific capacity about 120 g. p. m. for each foot of drawdown.
70±	Sandstone	Saltsburg sandstone±	40-50	----------	Force pump	1-3	See note	Domestic	Two wells 30 feet apart; 73-ft. well yields more than 3 g. p. m., the 140-foot well 50 gallons a day.
0	Shale	Saltsburg sandstone	0	----------	Natural flow	----------	90	Former municipal supply	Tabulated yield is aggregate for 8 spring openings.
140±	Shale	Brush Creek coal±	----------	—12	Gas engine, force pumps	----------	18-20 each	Former municipal supply	Five wells. Specific capacity less than 0.2 g. p. m. per foot of drawdown.
Near bottom	Carbonaceous shale	Clarksburg coal	----------	—30	Force pump	----------	4½	Domestic	----------
Near bottom	Gray sandstone	Morgantown sandstone	----------	—22	Automatic electric, force pump	3½	Ample	Domestic	Norwood community.
160	----------	Morgantown sandstone	----------	----------	None	----------	----------	None	
925	----------	Homewood sandstone	----------	----------		----------	----------		
1,684 and 1,723	Sandstone	Hundred-foot sand	----------	----------	None	----------	----------	None	
740	Coal	Upper Kittanning	----------	----------	None	----------	2±	None	Water-bearing members cased off.
1,040 and 1,085	Sandstone	Homewood sandstone	----------	----------	----------	----------	----------	----------	
1,770	Sandstone	Murrysville sand	----------	----------	----------	----------	½±	----------	
1,850	Sandstone	Murrysville sand	----------	----------	----------	----------		----------	

No. on Fig. 35	Location: Nearest P. O.	Location: Distance and direction from P. O.	Owner or name	Topographic situation	Altitude above sea level	Depth of well	Diameter of well
					Feet	Feet	Inches
	Tarentum Borough						
1018	Tarentum		Graff Bennett Co.	Hillside	870	2,300	----
	Upper Saint Clair Township						
			Espey heirs No. 1	----	1,070	----	----
			M. Fife No. 1	----	1,035	2,750	----
	Versailles Township						
312			Rainbow Gardens	Valley	820	60±	8
313			Flower Garden	Valley	780	77	8-6
1034	McKeesport ----	3 mi. NE.	Julius Kunkle	Hillside	1,030	3,300	----
1035	McKeesport ----	4 mi. E.	Sherrick	Valley	900	----	----
1036	McKeesport ----	2½ mi. SE.	Oliver Evans No. 1	Ridge crest	1,065	----	----

Chief aquifer			Depth to which well is cased	Water level above (+) or below (—) surface	Method of lift	Capacity of pump	Rate of inflow	Use of water	Remarks
Depth below surface	Character of material	Geologic horizon							
Feet			Feet	Feet		Gallons per minute	Gallons per minute		
454 and 461	Sandstone	Homewood sandstone			None			None	Salt water. Formerly used as source of salt.
828	Sandy shale	Patton shale (?)							Salt water.
1,247	Sandstone	Murrysville sand							"Fresh" water, highly concentrated in bicarbonates.
585	Sandstone	Saltsburg sandstone			None		2½	None	Water-bearing formations cased off.
880	Coal	Lower Freeport					½		
940	Coal	Upper Kittanning					1		
1,215	Sandstone	Homewood sandstone							
2,123	Sandstone	Hundred-foot sand					2½	None	Hole dry through Burgoon sandstone.
45	Sandstone(?)	Saltsburg sandstone	20	—20	Electric, suction pump		Maximum 114(?)	Swimming pool	Group of 5 wells; serious interference when several are pumped simultaneously.
35 and 65	Friable sandstone	Buffalo sandstone		—25	Manual, force pump	1–3	2½	Drinking	Amusement park.
55		Morgantown sandstone (?)			None			None	Cased off.
600	Coal	Middle Kittanning							Some gas with water.
270	Sandy shale	Mahoning sandstone±			None			None	Salt water. Water-bearing members cased off.
590	Sandstone and shale	Homewood sandstone							Salt water.
730	Sandstone	Connoquenessing sandstone							Salt water.
1,584	Sandstone	Murrysville sand					Large		Reported as "fresh" water.
845	Sandstone	Homewood sandstone			None			None	Salt water. Peoples Natural Gas Co. No. 1689.
1,785	Sandstone	Murrysville sand							Salt water.

No. on Fig. 35	Location: Nearest P. O.	Location: Distance and direction from P. O.	Owner or name	Topographic situation	Altitude above sea level	Depth of well	Diameter of well
					Feet	Feet	Inches
	West Deer Township						
239	Curtisville	1⅛ mi. W.	C. A. Porter	Terrace	1,170	47	6¼
	Curtisville	1⅛ mi. W.	C. A. Porter No. 1	Terrace	1,170	1,828	
240	Curtisville	0	Ford Collieries Co.	Hillside	1,060	160	6¼
	Curtisville	0	Ford Collieries Co.	Hillside	1,050±	65–110	6¼
241	Curtisville	¾ mi. W.	Ford Collieries Co.	Hilltop	1,080	597	6¼
242	Curtisville	1¼ mi. NE.	B. & L. E. R. R.	Stream head	1,080	72	8
243	Curtisville	½ mi. S.	Frank Dominica	Valley	1,040	210	6
244	Curtisville	1 mi. SE.	B. & L. E. R. R.	Valley	1,000	71	6
245	Russellton	1⅝ mi. W.	Ford Collieries Co.	Hillside	1,000	135	6¼
246	Russellton	1 mi. W.	Henry Bumgartel	Upland	1,140	38	6¼
247	Russellton	¾ mi. NE.	B. & L. E. R. R.	Valley	950±	425	4½
1023	Bakerstown	1¼ mi. SE.	Hunter	Valley	1,000	1,430	
	Wilkins Township						
			John A. Bloyd		860	3,235	
			Pittsburgh Meter Co. No. 1		750	2,106	

Chief aquifer: Depth below surface	Chief aquifer: Character of material	Chief aquifer: Geologic horizon	Depth to which well is cased	Water level above (+) or below (—) surface	Method of lift	Capacity of pump	Rate of inflow	Use of water	Remarks
Feet			Feet	Feet		Gallons per minute	Gallons per minute		
Near bottom	Shale	Bakerstown coal ±			Manual, force pump	1-3	Ample	Domestic, stock	
1,350	Sandstone	Murrysville sand			None		Large	None	Salt water.
1,519	Sandstone	Hundred-foot sand					1/10±		Salt water.
Near bottom		Butler sandstone (?)	120±		None			Formerly domestic	Mine No. 2 boarding house.
Near bottom	Sandstone	Mahoning sandstone	25-60		Electric, force pump		1/5 to 1	Domestic	Mine No. 2. Formerly about 20 wells in use; all but 3 have been drained by failure of mine roof and abandoned.
Near bottom	Shale	Connoquenessing sandstone ±	200±		Electric, force pump		1±	Domestic	Mine No. 2, mine superintendent's dwelling. Not plotted on Fig. 35.
Near bottom		Mahoning sandstone (?)	30		Manual, force pump	1-3		Drinking	Culmerville station.
Near bottom		Kittanning sandstone ±	112		Force pump		Inadequate	Domestic	
Near bottom		Mahoning sandstone ±	51	-39	Manual, force pump	1-3	Ample	Drinking	Curtisville station.
90	Shale	Brush Creek coal ±	20	-30±	Force pump		5+	Domestic	Mine No. 3. Wells usually less than 100 feet deep. A few wells find water 50 feet below surface in sandstone.
38	Top of sandstone	Saltsburg sandstone			Manual, force pump	1-3	Ample	Domestic	
Near bottom		Kittanning sandstone ±	125±	-200	Windmill, force pump	3	Small	Formerly domestic	Russellton laborers' dwellings. Wells less than 125 feet deep drained by slump of coal mine roof. Present supply from treated mine water.
542	Coal	Brookville coal			None				Cased off. Water well 48 feet deep reaches Brush Creek coal±.
580	Sandstone	Homewood sandstone					Large		Cased off.
1,430	Sandstone	Hundred-foot sand					8±		Salt water, produced with oil.
615	Coal	Lower Kittanning ±			None		1	None	Cased off.
30		Ames limestone ±			None		Large	None	Fresh water.
190		Buffalo sandstone ±							Salt water.
1,600	Sandstone	Murrysville sand					Large		Salt water.

[a] Analysis of water by U. S. Geological Survey.
[b] Flowing well or spring.

Driller's log of A. D. Bruening well near Warrendale

(No. 226, Fig. 35.)

	Thickness (Feet)	Depth (Feet)
Disintegrated sandstone	23	0–23
Shale, soft	3	23–26
Shale, hard	20	26–46
Sandstone, dense and fractured	2	46–48
Shale, white	10	48–58
Limestone (Woods Run)	5	58–63
Sandstone, pebbly and friable, water-bearng 65-70 feet	7	63–70
Red shale, small yield of water	12	70–82

Driller's log of diamond drill boring on J. W. Carlisle farm, half a mile east of Bakerstown

	Thickness (Feet)	Depth (Feet)
Soil	6	0– 6
Sandy shale, light	25	6– 31
Shale, dark	27.4	31– 58.4
Sandy shale, dark	4.0	58.4– 62.4
Shale, dark	10.4	62.4– 72.8
Coal (Bakerstown)	0.1	72.8– 72.9
Sandy shale, light	18.5	72.9– 91.4
Shale, black	0.6	91.4– 92.0
Fireclay	15.6	92.0–107.6
Shale, variegated	18.6	107.6–126.2
Fireclay	13.3	126.2–139.5
Shale, light	8.0	139.5–147.5
Shale, clayey	1.0	147.5–148.5
Shale, light	1.9	148.5–150.4
Sandstone (Buffalo)	2.7	150.4–153.1
Shale, light	0.7	153.1–153.8
Coal, bony (Brush Creek?)	6.4	153.8–160.2
Fireclay	4.8	160.2–165.0
Shaly sandstone	24.5	165.0–189.5
Shale, dark	6.4	189.5–195.9

(Note. Buffalo sandstone ranges from 3 to 45 feet in thickness in other borings of this district, and is usually water-bearing.

Partial log of South Penn Oil Company's well No. 3 at Sturgeon naphtha plant

(No. 308, Fig. 35.)

	Thickness (Feet)	Depth (Feet)
Sandstone (Morgantown, Murphy sand), water-bearing	85	75–160
Shale	73	160–233
Sandstone (Saltsburg, Hurry-up sand), water-bearing	45	233–278
Shale	35	278–313
Sandstone, black	20	313–333
Sandstone	8	333–341
Limestone, dense	2	341–343
Shale and sandstone, interlaminated	39	343–382
Clay shale, black	10	382–392
Sandstone (Buffalo or Little Dunkard), water-bearing	7	392–399
Shale, light and black	26	399–425

Driller's log of boring at Ford Collieries Mine No. 3, at Curtisville

(Adjacent to well No. 245, Fig. 35.)

	Thickness (Feet)	Depth (Feet)
Soil	14	0– 14
Limestone (Brush Creek), water at base	20	14– 34
Shale, red	12	34– 46
Shale and sandstone	25	46– 71
Sandstone (upper part of Mahoning), water at base	15	71– 86
Shale and sandstone, interlaminated	38	86–124
Sandstone (lower part of Mahoning), gray	25	124–149
Shale and sandstone, interlaminated, 1 gallon water per minute at 156 feet	12	149–161
Clay	3	161–164
Sandstone and shale	5	164–169
Coal (Upper Freeport)		169–

Note. Conduit for pump discharge from mine drainage sump.

Partial log of B. & L. E. R. R. Co.'s deep well at Russellton

(Site No. 247, Fig. 35.)

	Thickness (Feet)	Depth (Feet)
Fractured roof beds above mine on Upper Freeport coal	300	0–300
Shale	20	300–320
Sandstone (Butler), not water-bearing	15	320–335
Shale	50	335–385
Sandstone (Freeport), not water-bearing	20	385–405
Sandy shale	20	405–425
Carbonaceous shale (U. Kittanning coal?) water-bearing	6	425–431
Sandstone (Worthington), water-bearing, static level 200 feet below surface	9	431–440

Note. Well at laborers' dwellings drilled in 1910; yield less than 1 gallon per minute.

Driller's log of B. & L. E. R. R. Co.'s well at North Bessemer

(No. 291, Fig. 35.)

	Thickness (Feet)	Depth (Feet)
Soil	3	0– 3
Shale	10	3– 13
Sandstone (Morgantown), water at 30 feet	27	13– 40
Shale, red	58	40– 98
Shale, gray	13	98–111
Shale, red	45	111–156
Coal (Harlem?)	1	156–157
Shale, red	38	157–195
Sandstone (Saltsburg), hard and not water-bearing	62	195–257
Shale	1	257–258

Note. Well near engine house; inadequate and never used. Well No. 290, located in Plum Creek bottom nearby, found uppermost portion of Saltsburg sandstone to yield water copiously.

BUTLER COUNTY

TOPOGRAPHY AND DRAINAGE

Butler County, the northernmost of the six counties covered by this report (See Fig. 1) lies wholly within the Kanawha section of the Appalachian Plateaus. Allegheny River touches the county at its extreme northeastern and southeastern corners and receives the drainage from the eastern fourth of the area. Fully three-fourths of the county, however, is drained into Beaver River by its piratical westward-flowing tributaries, Slippery Rock Creek, Muddy Creek, and Connoquenessing Creek. Away from the major streams, Butler County is a terrane of smooth flat-topped hills or elongate ridges and open valleys of rounded contour, a product of the sub-mature dissection of the Allegheny peneplain. This erosion surface, of which the level ridge crests are remnants, is about 1,350 feet above sea level along the southern boundary of the county and rises northward to an elevation of approximately 1,575 feet above sea level in the northeastern corner. The local relief is of the order of 200 to 300 feet. The major streams, however, occupy more youthful trenches, that of Allegheny River being cut 550 to 625 feet below the peneplain surface. The maximum relief within the county is somewhat greater, being approximately 835 feet. In such a topographic environment there exists a moderate range in the conditions of ground water occurrence, inasmuch as a relatively thick succession of beds of very different water-bearing properties may be exposed within a very small area.

AREAL GEOLOGY

The strata exposed in Butler County range from uppermost Pocono to upper Conemaugh in age and become progressively younger toward the south. The oldest beds, the upper portion of the Burgoon sandstone, crop out only in three small areas in the Allegheny Valley of the extreme northeastern corner of the county (See Pl. I). The youngest, at the approximate horizon of the Clarksburg limestone of the Conemaugh, cap some of the highest ridges in the southwestern corner of Adams Township in the vicinity of Mars Borough. Accordingly, the exposed section is nearly 1,000 feet thick and is broken by the one major unconformity of the region, the pre-Pottsville. Beds of Pottsville age crop out only in relatively small areas in the Allegheny Valley and in the bed of Slippery Rock Creek in the northern part of the county. Each of the two overlying formations occupies approximately half the total area. The Allegheny formation, the lower of the two, extends almost without interruption over the northern third of the county and continues southward in the larger valleys somewhat beyond the latitude of the city of Butler. It also crops out in the southeastern part of the county along the axis of the Kellersburg anticline (Pl. I) in the valleys of Bull Creek and Rough Run, and on the axis of the Amity anticline in the valley of Little Buffalo Creek. The overlying Conemaugh formation covers extensive areas south of Muddy Creek. These consolidated rocks are overlain by tongues from the frontal apron of the Wisconsin stage of glaciation in the extreme northwestern part of the county, and, in the Allegheny Valley of the eastern part, by remnants of the early glacial (Illinoian) valley train.

GEOLOGIC STRUCTURE

Viewed broadly, the Carboniferous strata have a general southward or southwestward dip within Butler County, lying as they do on the eastern flank of a very broad geosyncline (See pages 28-29). This general dip is interrupted, however, by several parallel folds whose axes strike approximately N.20°-60°E. In succession from the northwest, the folds which have been designated by geographic names are: the Harrisville syncline, in the northwestern corner of the county; the Sewickley syncline and Brush Creek anticline in the southwestern corner; the Mount Nebo and Bradys Bend synclines, whose axes merge farther south in Allegheny County; the Kellersburg anticline; McMurray (Boggsville) syncline; and Amity anticline. All these axes plunge gently southwestward. The folds of the southeastern part of the county are the deeper and more persistent. These structures are represented on the map (Pl. I) by contours, or lines connecting points of equal elevation, drawn as though on the base of the Pittsburgh coal as an index bed. Inasmuch as the strata are essentially conformable throughout the exposed section, it follows that each has been deformed in the same degree as the index bed, so that the change in elevation of a given water-bearing member between two well sites may be ascertained approximately from the map. A preceding section (pp. 35-36) has discussed the relation of such structural features to the occurrence of ground water.

GROUND WATER RESOURCES

General features

The several formations which are sources of potable water in Butler County are embodied in the subjoined table with references to the pages on which their water-bearing properties are discussed in detail. Not all of these members are sources of potable water throughout the county, the lower beds of the Allegheny formation and the underlying rocks containing saline waters in the southern part of the county.

In general, nothing but highly concentrated brines will be found below regional drainage base. Furthermore, drilling more than 350 to 400 feet in depth in search of a non-saline water supply is not likely to be successful in any part of the county. The quality of the ground waters is shown by the analyses of representative samples which are tabulated on pages 71-73, and are discussed further in the descriptions of the individual members to which reference has been made. The known and potential areas of artesian flow within the county are noted on page 65.

Sources of fresh water in Butler County

Formation and member	Page
Late glacial (Wisconsin) gravel	
Frontal apron deposits	122
Early glacial (Illinoian) gravel	
Allegheny-Ohio valley train	124
Conemaugh formation:	
Saltsburg sandstone	170
Bakerstown coal	174
Buffalo sandstone	175
Cambridge limestone	177
Brush Creek limestone	177
Brush Creek coal	177
Mahoning sandstone	178
Allegheny formation:	
Upper Freeport limestone and underlying shales	185
Butler sandstone	185
Lower Freeport coal	186
Freeport sandstone	186
Upper Kittanning coal	187
Middle Kittanning coal	187
Worthington sandstone	187
Lower Kittanning coal	189
Kittanning sandstone	189
Vanport limestone	190
Clarion coal	191
Clarion sandstone	191
Brookville coal	193
Pottsville formation:	
Homewood sandstone	193
Connoquenessing sandstone	196
Pocono formation:	
Burgoon sandstone	198

In the southwestern corner of the county, in the vicinity of Zelienople and Evansburg and elsewhere, the static level of the salt water contained in the deep water-bearing beds is above that of the fresh water from shallower sources. Hence the fresh waters may become contaminated with brine near oil wells whose casings are defective or inadequate. At well 188 of Forward Township (Fig. 36 and p. 270) the static level of the brine is approximately 50 feet below the surface. Near the First National Bank in Zelienople, salt water was struck at a depth of 142 feet in the Clarion sandstone and rose within 40 feet of the surface. The brines flow by artesian pressure from the annular space between casings of several wells located on the flood plain of Connoquenessing Creek, in the same district.

Municipal supplies

Citizens Mutual Water Co. of Butler. Although the city of Butler (population 23,568) obtains its water supply from storage reservoirs on Connoquenessing and Thorn creeks, several groups of citizens have developed ground water supplies. Of these the largest is the Citizens Mutual Water Co. This organization has drilled 10 wells ranging in depth from 177 to 441 feet, which tap the Clarion and Homewood sandstones, a single lithologic unit in this vicinity. Wells Nos. 6 and 8, located on Breadin Avenue in the northwestern corner of the borough No. 166, Fig. 36 and p. 262) are 380 feet and 397 feet deep respectively; the driller's log of well No. 8 is given on page 287. The casing head elevation of each is approximately 1,140 feet above sea level. Each of these wells has a reported capacity of 8 to 10 gallons per minute, and is equipped with a deep well force pump driven by a gas engine. Wells Nos. 9 and 10 (No. 167) are in the central part of the

borough half a mile south of Nos. 6 and 8 and are 225 feet in depth. Further, they are but 5 feet apart and are pumped as a unit, with separate deep well force pumps actuated by a common crankshaft driven by a 7-horsepower gas engine. The aggregate rate of yield is 20 gallons per minute for 12 hours daily, the correlative drawdown being reported as 25 feet. The quality of the water is shown by the analysis of sample No. 167 tabulated on page 72. Well No. 7, within a few yards of Nos. 9 and 10 and of similar depth and capacity, is pumped 24 hours daily. Wells Nos. 3 and 4, which are 202 feet and 206 feet deep respectively, are about 175 yards east of well No. 7 and at approximately the same elevation. Each has a reported capacity of 15 gallons per minute, although they are usually held in reserve. The water from the several wells is raised to a 100,000-gallon reservoir on a hilltop a quarter of a mile east of well No. 8 and at an elevation of 1,265 feet above sea level. Thence it is distributed by gravity through 6 miles of 6-inch, 4-inch, and 2-inch mains. During July, 1926, the average daily consumption was approximately 45,000 gallons.

Well No. 1 was drilled at a site close to the main reservoir, but "lost its water" at 441 feet; it was subsequently plugged above the base and shot at a point 325 feet beneath the surface. It is reported, however, that this development effected an ultimate yield of only 1½ gallons per minute. The reported phenomenon of a sudden drop in the static level of the ground water is unauthenticated, although so far as the writer is aware, it is the only reputed case of notable subnormal pressure head in a water-bearing stratum which lies below the near by surface drainage ways, at least in so far as the source beds of the potable shallow waters are concerned. Well No. 2 exhibited a similar marked drop of the water surface at a depth of 177 feet. In this case, however, the drilling had not reached the level of the surface streams and had probably penetrated a perched or a semi-perched body of ground water in impermeable shaly rocks. Consequently, when a pervious bed was encountered the level of water in the well dropped to the main water table.

Evansburg. The municipal water supply of Evansburg (Evans City postoffice; population 1,561) is derived from 16 drilled wells in the valley of Likens Run, a tributary stream which enters Breakneck Creek about one mile west of the city. These wells are arranged in three groups, each of which is contained within a circle about 100 yards in diameter. The most easterly group of 5 wells is just west of the highway leading westward from Evansburg to Harmony and a quarter of a mile west of Breakneck Creek. These are 6-inch wells ranging in depth from 120 to 160 feet and tapping the Worthington sandstone. The average casing-head elevation is approximately 930 feet above sea level. Half a mile to the southwest, up the tributary valley, is a second group of 6 wells (No. 183, Fig. 36 and p. 272) of which at least two penetrate the Homewood sandstone between 251 and 280 feet beneath the surface. Still another half a mile upstream is a third group of 5 wells (No. 182), from 100 feet to 144 feet deep, which also tap the Worthington sandstone. This third group was drilled in 1923. Each group is pumped as a unit, the wells being equipped with deep well force pumps actuated by pump-jacks of the well-known Pennsylvania oil field type and shackle rods which radiate from a centrally-located

gas engine. The water flows from the wells through a gravity main to a gathering tank at the easternmost well field, and is pumped thence through a 6-inch force main to a 1,250,000-gallon reservoir on a hilltop in the northern edge of the borough at an altitude of 1,225 feet above sea level. Distribution is effected through a 6-inch gravity main 1.5 miles long. The average daily consumption is estimated at 50,000 gallons, of which about 20 per cent is by minor industries. Nothing is known of the specific capacities of the wells or of possible changes in the static level of the ground water since the first wells were drilled in 1910.

Mars. The municipal water supply of Mars (population 1,302) is derived from two drilled wells in the valley of Breakneck Creek at the southeastern corner of the borough (No. 214, Fig. 36), also from two hillside springs—Kinkade Spring 100 feet west, and Kennedy Spring 525 feet north of the well site. No. 1 well is 6 inches in diameter and 90 feet deep, and reaches the top of the Mahoning sandstone; No. 2 well is 8 inches in diameter and 194 feet deep and must penetrate the Mahoning sandstone completely. Kinkade Spring, which is supplied by the Saltsburg sandstone, discharges into well No. 2 through a 4-inch pipe. Each well is equipped with a Downie deep well force pump of 90 gallons per minute rated capacity, belt connected to a 20-horsepower gas engine. The specific capacities of the wells are not known. The average daily consumption is about 40,000 gallons, of which 20 per cent is by minor industries, although it is reported that the combined yield of the two wells during the dry season is but 36,000 gallons per day. Distribution is by gravity from a 64,000 gallon reservoir on a hilltop just outside the borough line and about 200 feet above the pumping station.

Millerstown. Millerstown Borough (Chicora postoffice; population 1,052) is supplied by a private company, the Millerstown Water Works, from drilled wells which tap the Worthington sandstone. The main supply is obtained from well No. 5, which is 6 5/8 inches in diameter and 60 feet deep, located on the north bank of Buffalo Creek at an altitude of 1,180 feet above sea level, (No. 159, Fig. 36). The static level of the ground water is less than 1 foot below the surface of the ground. The well is equipped with a Rumsey triplex force pump with a reported discharge of 55 gallons per minute and a drawdown of 10 feet while pumping steadily. Water is pumped directly to two 61,000-gallon tanks on the hilltop north of the borough at an altitude of 1,380 feet above sea level, and is distributed thence by gravity. Two wells, Nos. 3 and 4, are drilled 160 and 190 feet deep, respectively, from a site on the hillside about 80 feet above well No. 5. Each of these yields about 30 gallons per minute to an air lift pump, one discharging into a 2,520-gallon receiving basin and the other into a 42,000-gallon wooden tank. Two Campbell pumps, rated capacity 85 gallons per minute, driven by a 40-horsepower gas engine, lift the water to the main tanks on the hilltop above. These two wells are now maintained for standby services during periods of maximum demand or while well No. 5 is shut down; they operate as much as 180 hours per month during the summer. Two wells, Nos. 1 and 2, were drilled in 1874 to a depth of approximately 250 feet near the main storage tanks and for some years constituted the entire supply. They have long since been abandoned.

The reported average daily consumption is 85,000 gallons, of which 50,000 gallons serves the domestic demands, 30,000 gallons is used by the Baltimore & Ohio Railroad watering station, and 5,000 gallons by minor industries. The chemical nature of the water is shown by the analysis on page 72.

Slippery Rock. Slippery Rock Borough (population 1,165) is supplied by four drilled wells which tap the sandstone members of the Pottsville formation. Two wells (No. 118, Fig. 36), which are on the hilltop just east of the borough at an elevation of 1,435 feet above sea level, are 365 feet deep and 398 feet deep, respectively, and tap the Homewood sandstone, the static level of whose ground water is reported to be about 175 feet below the surface. Each of these wells is equipped with a deep well force pump, rated capacity 8 gallons per minute, although the reported yield is but 3½ gallons per minute. Water is pumped directly from these two wells into a 25,600-gallon tank just above the pumps and a 48,000-gallon elevated tank. A third well (No. 119) is on the hillside about 300 yards to the northwest at an altitude of 1,325 feet above sea level. It is 370 feet deep, penetrates both the Homewood and Connoquenessing sandstones, and yields at the rate of 7½ gallons per minute to an electrically-driven deep well force pump. The static level of the ground water is reported as 80 feet below the surface. The fourth well (No. 120) in a creek head in the northeastern part of the borough at an elevation of 1,300 feet above sea level, is 475 feet deep and likewise penetrates both the Homewood and Connoquenessing sandstones. At the time of the field examination the drilling of the well had just been completed but no capacity test had been made nor pumping equipment installed. Another well near the 370-foot well developed only a very small yield and was considered a failure. None of the wells was drilled deeper for fear of encountering salty water in the underlying Burgoon sandstone. The average daily consumption from the system is about 13,000 gallons, of which all goes to domestic uses.

The State Teachers College, at Slippery Rock, has a private system of three wells (Nos. 121, 122, and 123) which are 200 feet, 275 feet, and 300 feet deep, respectively. These also tap the Pottsville sandstones. The rates of yield range from 4 to 16½ gallons per minute from the individual wells, and the average daily consumption is from 10,000 to 12,000 gallons.

West Winfield. The village of West Winfield (population 526), in the valley of Rough Run at the eastern edge of Butler County, derives its supply from an unnamed hillside spring (No. 205, Fig. 36) which issues from a pebbly facies of the Mahoning sandstone in the wall of the valley 350 feet above. The improvements at the source include suitable cut-off walls and covered infiltration pits 15 feet long, 10 feet wide, and 3 feet deep built at each of the two orifices. Thence the water flows by gravity to storage tanks and is distributed by a gravity main to meet the demand for domestic purposes. The minimum aggregate yield is somewhat less than 5 gallons a minute during the late summer, and barely is adequate for the demand.

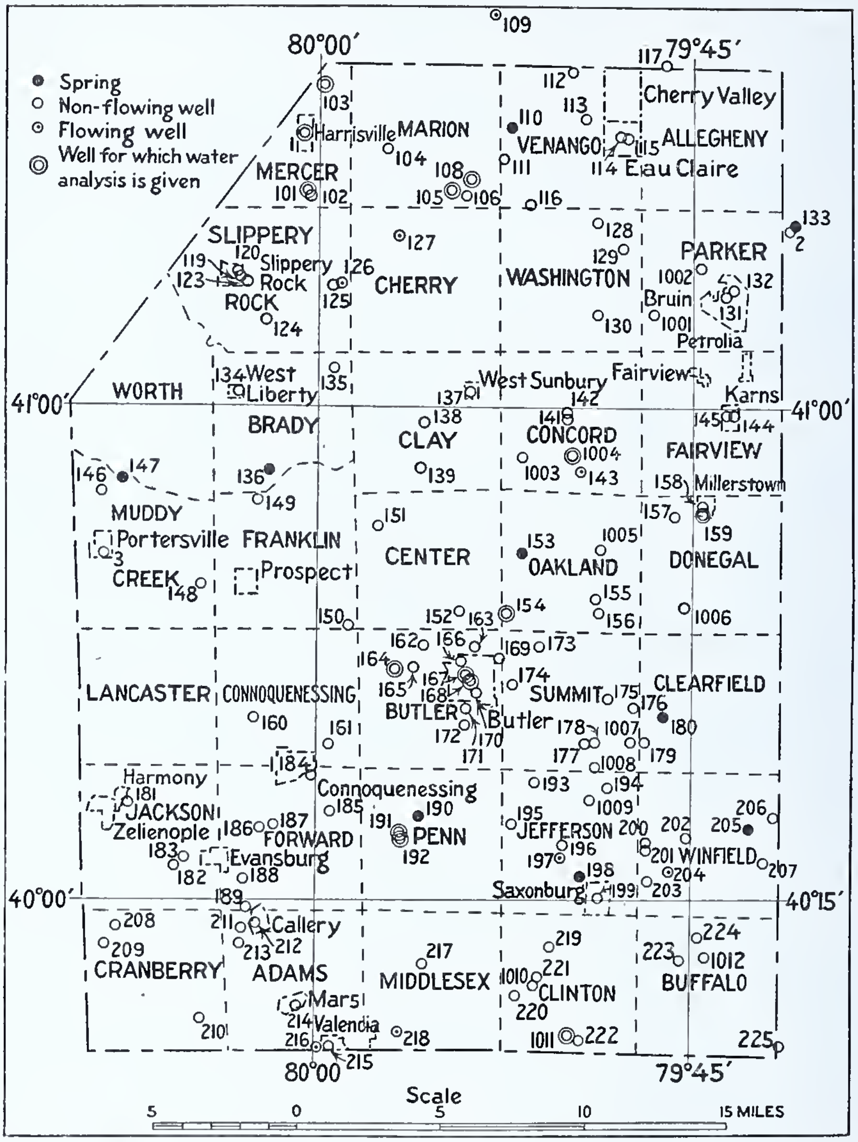


Figure 36. Map of Butler County showing location of wells and springs described in this report.

The following tables of typical wells are too wide to print so that the data for any well could be read horizontally across the left hand to the right hand page. This necessitated setting the type lengthwise of the page. Each right hand page is a continuation of the data on the left hand page which it faces. For ease in following the description of a single well from one page to the next, the townships and boroughs have been separated by horizontal lines.

TYPICAL WELLS AND SPRINGS IN BUTLER COUNTY, PA.

No. on Fig. 36	Location: Nearest P. O.	Location: Distance and direction from P. O.	Owner or name	Topographic situation	Altitude above sea level	Depth of well	Diameter of well
					Feet	Feet	Inches
	Adams Township						
211	Callery	2/3 mi. E.	W. E. Dunbar	Ridge crest	1,100	111	6 5/8
213	Callery	1 mi. SW.	E. J. Maier	Ridge crest	1,125	151	6 1/4
216[b]	Valencia	1/2 mi. W.	Kramer's packing plant	Valley	960	70	6 1/4
			John Kennedy	----------	----------	1,403	----------
			N. Hartung	----------	----------	287	----------
	Allegheny Township						
117	Eau Claire	3 mi. NE.	Will Drake	Upland	1,440	292	----------
	Brady Township						
134	Slippery Rock	4 mi. S.	Miscellaneous	Valley	1,220–1,280	30–72	6
135	West Sunbury	5 mi. W.	B. & L. E. R. R.	Valley	1,190	40–66	6
136[b]	Slippery Rock	7 mi. S.	Martsoff	Valley	1,220	----------	----------
	Bruin Borough						
131	Bruin	0	Miscellaneous	Valley	1,100	16–20	6
132	Bruin	0	Bruin Coal Co.	Hillside	1,105	150	6

[b] Flowing well or spring.

Chief aquifer: Depth below surface	Chief aquifer: Character of material	Chief aquifer: Geologic horizon	Depth to which well is cased	Water level above (+) or below (—) surface	Method of lift	Capacity of pump	Rate of inflow	Use of water	Remarks
Feet			Feet	Feet		Gallons per minute	Gallons per minute		
25	Black slate	Brush Creek coal	19½	—18	Manual, force pump	1–2	½	Domestic	
	Slate	Brush Creek coal ±	23½	—90				Domestic	
70	White sandstone	Mahoning sandstone	------------	+1	Manual, force pump	3–5	5	Packing plant	
1,174	------------	Murrysville sand	------------	------------	None	------------	------------	None	Salt water, cased off.
------------	------------	Lower part of Allegheny formation or Homewood sandstone	------------	------------	Gas or steam, force pump	5±	------------	Boiler feed	Used while drilling near by oil well.
215	Sandstone	Burgoon sandstone	175	—200	Gas engine, force pump	6½	------------	Domestic, stock	Well located in Venango County. Consumption 400 gallons per day.
------------	Sandstone	Clarion sandstone	18–25	—20 to 70	Manual, force pump	1–2	------------	Domestic	West Liberty community. A few wells find water in the Vanport limestone.
------------	Sandstone—?	Clarion sandstone	32	------------	Force pump	1–2	------------	Drinking and household	Four wells at Hallston Station and employees homes.
------------	Sandstone	Worthington sandstone	------------	------------	Natural overflow	------------	2	Domestic, stock	Spring 1¼ miles north of Isle community.
15	Sandstone	Homewood sandstone	------------	------------	Manual, force pump	1–3	1/20 to ½	Domestic	Consumption not more than 75 gallons per day for most wells.
105	Sandstone	Connoquenessing sandstone	------------	------------	Electric, force pump	15	------------	Cooling gas engines	Consumption about 7,000 gallons per day.

No. on Fig. 36	Location		Owner or name	Topographic situation	Altitude above sea level	Depth of well	Diameter of well
	Nearest P. O.	Distance and direction from P. O.					
					Feet	Feet	Inches
	Buffalo Township						
223	Sarver	1 mi. SW.	Wetzel	Hillside	1,060±	75–85	6
224	Sarver	0	American Natural Gas Co.	Valley	1,100±	49	8
225	Freeport	½ mi. NW.	Kerr Coal Co.	Valley	1,000	232	6¼
1012	Sarver	¾ mi. S.	Samuel Faulkner	Hillside	1,060	1,550+	----------
	Butler Township and Borough						
162	Butler	2¼ mi. NW.	Butler Street Railway Co.	Valley	1,060	225	6¼
163	Butler	1 mi. N.	Gilbreath and others	Hilltop	1,290	550	----------
164[a]	Butler	3 mi. W.	W. H. Bortmas	Upland	1,300	209	6
165	Butler	2¾ mi. W.	Butler & McGinness	Upland	1,320	127	6
166	Butler	0	Citizens Mutual Water Co.	Hillside	1,140	397	6¼
167[a]	Butler	0	Citizens Mutual Water Co.	Valley	1,000	225	8¼
168[a]	Butler	0	Butler Steam Laundry	Valley	1,020	101	8

[a] Analysis by U. S. Geological Survey.

Chief aquifer			Depth to which well is cased	Water level above (+) or below (−) surface	Method of lift	Capacity of pump	Rate of inflow	Use of water	Remarks
Depth below surface	Character of material	Geologic horizon							
Feet			Feet	Feet		Gallons per minute	Gallons per minute		
Near bottom	White sandstone	Mahoning sandstone		−50 to 60	Manual, force pump	1–2		Domestic	Group of 11 wells at Sarverville.
	Sandstone	Mahoning sandstone		−6	Suction pump			Cooling compressor engines	Consumption probably not less than 5,000 gallons per day.
40	Sandy shale	Saltsburg sandstone		−9					Well entered crevice at depth of 100 feet and drained upper aquifer.
145	Sandstone	Mahoning sandstone		−100	Manual, force pump	1–2		Domestic	Well located in Armstrong County.
703 and 713	Sandstone	Burgoon sandstone (70-foot sand)			None		½	None	Salt water, cased off. T. W. Phillips Gas & Oil Co.
1,350	Sandstone	Murrysville (Gas sand)			None		½	None	Salt water, cased off.
128	Slate	Worthington sandstone							
192	Friable sandstone	Kittanning sandstone	73		Force pump		85	Drinking, and swimming pool	Well No. 3 at Alameda Park. Has been pumped steadily for as much as 28 hours.
210	Sandy shale	Mahoning sandstone		−250	Electric, force pump		1	Domestic	Community well at Boulevard. Static level 60 feet below surface in 1925. Base reaches Homewood sandstone.
Near bottom	Slate	Mahoning sandstone	13	−139	Gasoline, force pump	5	13	Greenhouse	Near by well 205 feet deep yields only 1 g. p. m.
Near bottom	Slate	Brush Creek coal			Manual, force pump	1–2		Domestic	
197	White sandstone	Kittanning sandstone							
255	Sandstone	Clarion sandstone	144	−40	Gas engine, force pump	25	8–10	Public supply	Well No. 8 on Bredin Avenue.
145	Gray sandstone	Clarion sandstone	122	−60	Gas engine, force pump	50	20	Public supply	Well No. 9. Specific yield about 0.8 g. p. m. per foot of drawdown. Diameter at base is 4½ inches.
Near bottom	Black shale	Middle Kittanning (?) coal			Gas engine, force pump	15	15	Laundry	Consumption about 7,200 gallons per day 5 or 6 days a week.

No. on Fig. 36	Location: Nearest P. O.	Location: Distance and direction from P. O.	Owner or name	Topographic situation	Altitude above sea level	Depth of well	Diameter of well
					Feet	Feet	Inches
	Butler Township and Borough—Continued						
169	Butler	1¼ mi. NE.	B. & L. E. R. R.	Valley	1,010	95	6¼
170	Butler	0	Spang & Co.	Valley	1,025	195	8
171	Butler	1 mi. S.	Brown	Hillside	1,190	70	4⅞
172	Butler	1½ mi. S.	Basil Hilliard	Hillside	1,080	83	6
	Callery Borough						
212	Callery	0	Callery school	Valley	990	83	6⅝
	Center Township						
151	Euclid	4 mi. SW.	Graham Service Station	Valley	1,310	100	6
152	Butler	2½ mi. N.	Hendricks	Upland	1,325	300	----------
	Cherry Township						
127b	Boyers	3 mi. SW.	----------	Valley	1,180	----------	----------
	Clay Township						
138	Euclid	0	Miscellaneous	Hillside	1,300-1,335	50-100	6
139	Queen Junction	0	B. & L. E. R. R.	Valley	1,225	80	6½
140	Queen Junction	0	B. & L. E. R. R.	Valley	1,225	242	12

Chief aquifer			Depth to which well is cased	Water level above (+) or below (—) surface	Method of lift	Capacity of pump	Rate of inflow	Use of water	Remarks
Depth below surface	Character of material	Geologic horizon							
Feet			Feet	Feet		Gallons per minute	Gallons per minute		
92	?	Kittanning sandstone	32	—50±	Force pump	----------	30	Locomotive boilers	Butler Transfer freight yard. Small yield at depths of 18 and 46 feet in Worthington sandstone.
177	Sandstone	Kittanning sandstone	14	----------	Air lift	25	----------	Foundry, quenching tanks	No. 1 Well, consumption estimated 18,000 gallons per day or more.
Near bottom	Shale	Below Upper Freeport coal	50	----------	Force pump	1-2	Adequate	Domestic	Located at Graham Terrace.
Near bottom	----------	Butler sandstone (?)	----------	----------	Manual, force pump	1-2	Adequate	Domestic	----------
75	Sandy shale	Butler sandstone (?)	21	----------	Force pump	----------	1¼	Drinking	----------
Near bottom	Sandstone	Mahoning sandstone	60	----------	Manual, force pump	1-2	1+	Domestie	Iron-bearing water.
----------	----------	Worthington sandstone (?)	----------	----------	Force pump	----------	Adequate	Domestic, stock	----------
300±	----------	Burgoon sandstone (?)	----------	+	None	----------	Steady flow	None	Abandoned oil well plugged below Burgoon sandstone. Located at Nelson's Bridge.
Near bottom	Sandstone	Butler sandstone	----------	----------	Manual, force pump	1-2	Adequate	Domestic	Euclid community.
Near bottom	Sandy shale	Below Middle Kittanning coal	----------	—60±	Force pump	----------	----------	----------	Queen Junction tower
35 140 222	Sandstone White sandstone Dark gray sandstone	Butler sandstone Kittanning sandstone Homewood sandstone	----------	—35	Force pump	----------	----------	Locomotive boilers	Queen Junction. Not plotted on Fig. 36; near No. 139. Yield probably not less than 10 g.p.m.

No. on Fig. 36	Location: Nearest P. O.	Location: Distance and direction from P. O.	Owner or name	Topographic situation	Altitude above sea level	Depth of well	Diameter of well
					Feet	Feet	Inches
	Clearfield Township						
179	Herman	1½ mi. E.	Clarence Smith	Ridge crest	1,320	107	----------
180[b]	Herman	2½ mi. NE.	----------	Valley	1,195	----------	----------
	Clinton Township						
219	Saxonburg	2 mi. S.	B. & L. E. R. R.	Stream head	1,200	165	12
220	Saxonburg	3½ mi. SW.	A. T. Williams	Ridge crest	1,225	98	6
221	Saxonburg	3 mi. S.	B. & L. E. R. R.	Valley	1,170	75	6
	Saxonburg	3 mi. S.	B. & L. E. R. R.	Valley	1,170	227	12
222	Saxonburg	5½ mi. S.	B. & L. E. R. R.	Hillside	1,060	215	8
1010	Saxonburg	3 mi. S.	Walter Morrison	Valley	1,150	2,000+	----------
1011[a]	Saxonburg	5½ mi. S.	Mrs. Sarah Miller	Hillside	1,025	1,163	6¼

Chief aquifer: Depth below surface	Chief aquifer: Character of material	Chief aquifer: Geologic horizon	Depth to which well is cased	Water level above (+) or below (—) surface	Method of lift	Capacity of pump	Rate of inflow	Use of water	Remarks
Feet			Feet	Feet		Gallons per minute	Gallons per minute		
Near bottom	----------	Mahoning coal±	----------	—94	Manual, force pump	1–2	3	Domestic	Iron-bearing water.
----------	Joint crevice	Mahoning sandstone	----------	----------	None	----------	5	None	Spring. Iron-bearing water.
124	Sandstone	Mahoning sandstone	----------	-150±	Gas engine, force pump	250	110	Locomotive boilers	Well at Houseville yard. Yield about 275 g. p. m. in 1910, tabulated yield in 1917. Static level originally about 60 feet beneath surface. Four other wells 8, 10, and 14 inches in diameter, 125 to 161 feet deep, yield 25 to 100 g. p. m.
Near bottom	Shale	Brush Creek coal ±	----------	----------	Manual, force pump	1–2	Ample	Domestic	----------
30	Sandstone	Mahoning sandstone	50	-35	Force pump	----------	Ample	Drinking	Well at Ivywood station, formerly Bartley. Iron-bearing water shut off by casing.
----------	----------	Freeport sandstone (?)	----------	----------	Gas engine, force pump	----------	98	Locomotive boilers	Well at Ivywood yard. Tabulated yield in 1917.
150	Sandstone	Worthington sandstone	----------	-75	----------	----------	Small	----------	Well at Cunningham brick yard 2 miles north of Culmerville.
1,300	Sandstone	Murrysville sand	----------	300±	None	None	----------	None	Salt water, cased off.
445	Sandstone	Connoquenessing sandstone ±							
685	Sandstone	Burgoon sandstone ±	447	-250±	None	None	Large	None	Gas well being drilled September, 1926.
850	Sandstone	Squaw sand							
1,178	Sandstone	Murrysville sand							

No. on Fig. 36	Location: Nearest P. O.	Location: Distance and direction from P. O.	Owner or name	Topographic situation	Altitude above sea level	Depth of well	Diameter of well
					Feet	Feet	Inches
	Concord Township						
141	West Sunbury	3½ mi. E.	Hooker schoolhouse	Ridge crest	1,395	130	----------
142	West Sunbury	3½ mi. E.	Frank Ryder	Ridge crest	1,420	208	----------
143[b]	West Sunbury	4½ mi. SE.	----------	Valley	1,150	----------	12(?)
1003	West Sunbury	3 mi. SE.	G. W. Fleming No. 3	Stream head	1,280	----------	----------
1004[a]	West Sunbury	4 mi. SE.	Boyers	Upland	1,275	----------	----------
	Connoquenessing Township						
160	Connoquenessing	2½ mi. NW.	Greer McCandless	Hillside	1,220	123	6¼
161	Connoquenessing	1½ mi. NE.	Loyal Order of Moose	Upland	1,230	128	5⅝
	Cranberry Township						
208	Zelienople	4 mi. S.	Michael Klein	Ridge crest	1,190	194	6¼
209	Zelienople	5 mi. S.	Harvey Link	Upland	1,150	136	6¼
210	Mars	3½ mi. W.	W. F. Baird	Upland	1,200	96½	6⅝
			W. Garvin	----------	----------	1,523	----------
			Joseph Goehring No. 2	----------	----------	1,493	----------

Chief aquifer: Depth below surface	Chief aquifer: Character of material	Chief aquifer: Geologic horizon	Depth to which well is cased	Water level above (+) or below (—) surface	Method of lift	Capacity of pump	Rate of inflow	Use of water	Remarks
Feet			Feet	Feet		Gallons per minute	Gallons per minute		
125	Yellow sandstone	Mahoning sandstone	--	--	Force pump	1–2	Ample	Drinking	--
200	White sandstone	Butler sandstone	--	--	Force pump	--	Ample	Household	Hooker community.
300±	--	Burgoon sandstone	--	+3±	None	--	50	Municipal supply	Abandoned oil well plugged at base Burgoon sandstone. Flows into Boydstown reservoir, Butler municipal supply.
75	Sandstone	Butler sandstone	--	--	None	--	--	Cased off	T. W. Phillips Gas & Oil Co.
1,278	Sandstone	Hundred-foot sand	--	--	--	--	1	None	
1,000+	Sandstone	Hundred-foot sand	--	--	Force pump	--	1/5	None	Concentrated brine brought up with oil. Well is 1½ miles south of Hooker community.
120	Top of limestone	Upper Freeport limestone	--	--	Force pump	--	Ample	Domestic	Originally gave ample yield from Mahoning sandstone, at depth of 108 feet, but failed from drilling of numerous oil wells near by; since deepened.
50 and 97	Sandstone	Buffalo sandstone							
110	Base of limestone	Brush Creek limestone	36	--	Force pump	--	Ample	Swimming pool	--
188	White sandstone	Mahoning sandstone	--	-150	Force pump	--	Ample	Domestic	Could not be bailed down.
60	Crevice in shale	Cambridge limestone ±	18½	--	Force pump	--	Small	Domestic	--
92	Shale	Saltsburg sandstone	24½	--	Automatic electric, force pump	2(?)	--	Domestic	Dry-season decline in static level limits yield. Hendersonville community.
1,300	Sandstone	Murrysville sand	--	--	None	--	--	None	Uppermost salt water, cased off.
1,392	Sandstone	Hundred-foot sand	--	--	Force pump	--	--	--	Original yield 17½ g. p. m. salt water with oil in 1893; decreased to 5 g. p. m. in 1897. Since abandoned.

No. on Fig. 36	Location: Nearest P. O.	Location: Distance and direction from P. O.	Owner or name	Topographic situation	Altitude above sea level	Depth of well	Diameter of well
					Feet	Feet	Inches
	Donegal Township						
157[b]	Chicora	1 mi. W.	Silver Side Inn	Valley	1,190	----------	----------
1006	Fenelton	2½ mi. NW.	A. E. Donaldson, No. 3	Valley	1,230	----------	----------
	Eau Claire Borough						
114	Eau Claire	0	Bessie Kerr	Upland	1,510	160	----------
115	Eau Claire	0	Earl McCall	Upland	1,460	44	----------
	Forward Township						
184	Connoquenessing	¾ mi. SE.	J. N. Love	Stream head	1,190	71	6¼
185	Renfrew	1¾ mi. SW.	Girl Scout Camp	Valley	980	300	----------
186	Evans City	2 mi. NE.	Addison Boggs	Terrace	1,020	61	6¼
187	Evans City	2½ mi. NE.	Community Camp	Valley	940	106	6¼
188	Evans City	1 mi. SE.	Robert Irwin	Valley	1,000	45	6¼
189	Callery	¾ mi. NW.	Lew Kaufman	Hillside	1,070	211	6¼
	Franklin Township						
149	Prospect	3¼ mi. N.	E. A. Watson	Valley	1,190	50	----------
150	Butler	4½ mi. NW.	Miscellaneous	Upland	1,335	20	----------

Chief aquifer			Depth to which well is cased	Water level above (+) or below (—) surface	Method of lift	Capacity of pump	Rate of inflow	Use of water	Remarks
Depth below surface	Character of material	Geologic horizon							
Feet			Feet	Feet		Gallons per minute	Gallons per minute		
500(?)	----	Burgoon sandstone (?)	----	+1	None	----	20	Service station	Abandoned oil well plugged below Burgoon sandstone
125	Sandstone	Worthington sandstone	----	----	None	None	----	----	Cased off.
1,250±	----	Hundred-foot sand	----	----	Force pump	----	1/20	----	Salt water.
150	Sandstone	Homewood sandstone	----	----	Force pump	----	Ample	Domestic	----
Near bottom	Sandstone	Kittanning sandstone	----	----	Force pump	----	Ample	Domestic	----
Near bottom	Sandstone	Mahoning sandstone	43	----	Force pump	----	Ample	Domestic	Iron-bearing water.
Near bottom	Sandstone	Homewood sandstone	----	----	Gas engine, force pump	25	25+	Swimming pool	Has been pumped steadily as much as 48 hours.
59	Shale	Below Upper Kittanning coal	34	—10	Force pump	----	Ample	Domestic	----
102	Sandstone	Kittanning sandstone	39	----	Force pump	----	Large	Household	Small yield at depth 50 feet in Worthington sandstone.
16	Shale	Below Lower Freeport coal	15½	----	Force pump	----	Ample	Domestic	In near by oil wells salt water from Murrysville sand rises within 52 feet of surface. Some wells slightly saline from that source.
202	Sandstone	Butler sandstone	----	----	Force pump	----	Large	Domestic	
Near bottom	Shaly sandstone	Worthington sandstone	----	----	Force pump	----	Ample	Domestic	Isle Community. Iron-bearing water.
10-20		Weathered debris from Saltsburg (?) sandstone	20	----	Manual, suction pump	1-3	Ample	Domestic	Dug well; may be inadequate in extremely dry seasons.

No. on Fig. 36	Location: Nearest P. O.	Location: Distance and direction from P. O.	Owner or name	Topographic situation	Altitude above sea level	Depth of well 339	Diameter of well
					Feet	Feet	Inches
	Harrisville Borough						
1[a]	Harrisville	0	Cathcart Hotel	Upland	1,314	14	-----------
	Jackson Township						
181	Harmony	¼ mi. S.	Bert Talbo	Valley	920	51	6¼
182	Evans City	1½ mi. W.	Evansburg Borough	Valley	975	100-144	6¼
183	Evans City	1 mi. W.	Evansburg Borough	Valley	950	269 and	6¼
	Jefferson Township						
193	Great Belt	2¾ mi. W.	C. C. Trimbur	Upland	1,340	102	-----------
194	Great Belt	0	Willis Bachman	Hillside	1,310	140	-----------
195	Great Belt	2¾ mi. SW.	Forest Bertner	Hillside	1,290	193	5⅝
196	Saxonburg	2¼ mi. NW.	Weitzel	Valley	1,145	52	5⅝
197[b]	Saxonburg	2 mi. NW.	-----------------------------------	Valley	1,120	-----------	-----------
198[b]	Saxonburg	1 mi. NW.	Saxonburg Mineral Springs	Hillside	1,200	-----------	-----------
1009	Great Belt	1 mi. SW.	D. F. Nagley	Ridge crest	1,290	-----------	-----------

Chief aquifer			Depth to which well is cased	Water level above (+) or below (—) surface	Method of lift	Capacity of pump	Rate of inflow	Use of water	Remarks
Depth below surface	Character of material	Geologic horizon							
Feet			Feet	Feet		Gallons per minute	Gallons per minute		
12	Fine gravel	Glacial outwash	------	Unknown	Manual, suction pump	2–3	Ample	Household	Dug well.
51	Sandy shale	Below Lower Kittanning coal	49	------	Force pump	------	Ample	Household	Near by well found salt water in the Clarion sandstone, at depth of 147 feet; static level 40 feet below the surface.
45 and 80	Shale	Below Upper Kittanning coal	21–79	------	Gas engine, force pump	10±	------	Municipal supply	Group of 5 wells on Reinhart farm.
251	White sandstone	Homewood sandstone	160	—40	Gas engine, force pump	10±	50(?)	Municipal supply	Salt water at 333 feet in well No. 2 and plugged off. Worthington sandstone yields about 1 g. p. m. at 185 feet in the same well.
95	Sandstone	Buffalo sandstone	------	—80	Force pump	------	Ample	Domestic	
140	Shale	At base Buffalo sandstone	------	—98	Force pump	1–2	------	Domestic	Barely ample for household needs.
Near bottom	Shale	Mahoning coal	34	------	Force pump	1–2	------	Domestic	Located ¾ mile south of Shiloh Church.
Near bottom	Shale	Below Brush Creek coal	19	------	Force pump	------	------	Domestic	Located ¼ mile north of Jefferson Center. Most wells in the vicinity less than 50 feet deep yield iron-bearing water.
80(?)	Sandstone	Mahoning sandstone (?)	------	+20	None	------	200	None	Abandoned oil well, plugged at unknown depth. Reported depth of aquifer somewhat doubtful.
------	Sandstone	Saltsburg sandstone	------	------	None	------	1	Resort, medicinal	Spring.
565	Sandstone	Homewood sandstone	------	------	None	------	------	None	
1,523	Sandstone	Hundred-foot sand	------	------	------	------	------	None	Salt water.

No. on Fig. 36	Location: Nearest P. O.	Location: Distance and direction from P. O.	Owner or name	Topographic situation	Altitude above sea level	Depth of well	Diameter of well
					Feet	Feet	Inches
	Karns City Borough						
144	Karns city	0	Miscellaneous	Valley	1,215	60–80	----------
145	Karns City	0	Pennsylvania Refining Co.	Valley	1,215	550±	8
	Marion Township						
104	Harrisville	3 mi. E.	Silver Fox Farm	Hillside	1,300	116	6
105[a], [b]	Boyers	$\frac{3}{4}$ mi. W.	Pittsburgh Limestone Co.	Valley	1,200	100	6
106	Boyers	$\frac{1}{4}$ mi. SW.	Pittsburgh Limestone Co.	Hillside	1,235	150±	6
107	Boyers	$\frac{1}{4}$ mi. SW.	Pittsburgh Limestone Co.	Hillside	1,235	208	8
108[a]	Boyers	$\frac{1}{2}$ mi. N.	Henry Middendorf	Valley	1,200	250±	8
	Mars Borough						
214	Mars	0	Mars Borough	Valley	1,040	194	8
	Mars	0	Mars Borough	----------	----------	90	6
	Mercer Township						
101[c]	Forestville	$\frac{1}{2}$ mi. N.	B. & L. E. R. R.	Upland	1,320	85	4
102	Forestville	$\frac{1}{2}$ mi. N.	Dufford	Upland	1,320	40	6
103[a]	Harrisville	$1\frac{3}{4}$ mi. N.	Harry Greene	Hilltop	1,440	30	6

Chief aquifer			Depth to which well is cased	Water level above (+) or below (—) surface	Method of lift	Capacity of pump	Rate of inflow	Use of water	Remarks
Depth below surface	Character of material	Geologic horizon							
Feet			Feet	Feet		Gallons per minute	Gallons per minute		
Near bottom	Sandstone	Butler sandstone	-----	—50	Force pumps	1–3	Ample	Domestic	Wells 38–50 feet deep in shale drained by drilling of many oil wells near by.
Near bottom	Sandstone	Burgoon sandstone	-----	—5	Air lift, centrifugal pumps	-----	100–150	Boilers and condensers at oil refinery	Four abandoned oil wells redrilled to plug at base Burgoon sandstone. One formerly flowed slightly.
Near bottom	Sandstone	Homewood sandstone	-----	—96	Force pump	5±	Ample	Household stock	
Near bottom	Sandstone	Homewood sandstone	-----	+5	Natural flow	-----	5	Domestic	Company houses along Slippery Rock Creek.
Near bottom	Sandstone	Homewood or Connoquenessing sandstone	-----	—30	Steam, force pump	50 (?)	20	Domestic	Supplies 40 houses.
193	Sandstone	Burgoon sandstone	65	-----	Steam, force pump	-----	65	Boiler feed	Not plotted on Fig. 36. Near well 106.
-----	Sandstone	Burgoon sandstone	-----	+	Natural flow	-----	200	None	Abandoned oil well pluged at base Burgoon sandstone.
Near bottom		Well penetrates Mahoning sandstone	-----	-----	Gas engine, force pump	90	-----	Municipal supply	Combined yield of two wells is 36,000 gallons a day.
Near bottom	Reaches top	Well reaches top of Mahoning sandstone	-----	-----	Gas engine, force pump	90	-----	-----	
50	Limestone	Vanport limestone	55	-----	Manual, force pump	1–3	Small	Drinking	Harrisville station
-----	Crevices in shale	Lower Kittanning coal±	-----	-----	Manual, force pump	1–2	-----	None	Former domestic supply abandoned because of iron content.
23	Coal	Middle Kittanning coal	-----	—10	Manual, suction pump	1–3	Ample	Domestic	-----

No. on Fig. 36	Location		Owner or name	Topographic situation	Altitude above sea level	Depth of well	Diameter of well
	Nearest P. O.	Distance and direction from P. O.					
					Feet	Feet	Inches
	Middlesex Township						
217	Valencia	4½ mi. NE.	McCarty	Hillside	1,150	63	6¼
218[b]	Valencia	2½ mi. E.	James McNanny	Valley	1,150	28	6¼
	Millerstown Borough						
158	Chicora	0	Millerstown Water Works	Hillside	1,260	160 and 190	----------
159[a b]	Chicora	0	Millerstown Water Works	Valley	1,180	60	6⅝
	Muddy Creek Township						
146	Portersville	2½ mi. N.	Burnside school	Hillside	1,225	81	----------
147[b]	Portersville	2¾ mi. NE.	----------	Valley	1,160	----------	----------
148	Prospect	1¾ mi. W.	Roberts	Upland	1,375	80½	6
	Oakland Township						
153[b]	Butler	4½ mi. NE.	----------	Hillside	1,075	0	----------
154[a]	Butler	2½ mi. NE.	Kosko Coal and Gas Co.	Hillside	1,080	----------	6
155	Butler	5¼ mi. NE.	Joe Spicker	Ridge crest	1,320	72½	4⅞
156	Butler	5 mi. NE.	Charles Dunn	Ridge crest	1,330	171	----------
1005	Butler	6½ mi. NE.	C. H. Conway	Hillside	1,225	----------	----------

Chief aquifer: Depth below surface	Chief aquifer: Character of material	Chief aquifer: Geologic horizon	Depth to which well is cased	Water level above (+) or below (—) surface	Method of lift	Capacity of pump	Rate of inflow	Use of water	Remarks
Feet			Feet	Feet		Gallons per minute	Gallons per minute		
59	White sandstone	Buffalo sandstone	20	—28	Manual, force pump	1–2	Ample	Domestic	Other near by wells are not adequate for unlimited household use.
Near bottom	Gray sandstone	Saltsburg sandstone	18	±0	Manual, force pump	3	3	Domestic	Flows through 1-inch nipple 3 feet below pump base.
101	Sandstone	Worthington sandstone	100		Air lift			Municipal stand by	Yield from two wells is 60 g. p. m.
28	Sandstone	Worthington sandstone	28	±0	Gas engine, suction pump		50–55	Municipal supply	Pumped continuously in warm months.
72	Shale	Clarion coal±	65	—35	Manual, force pump	1–3		Drinking	
0	Limestone	Vanport limestone			None		5	Drinking	Spring.
Near bottom	Crevices in shale	Mahoning sandstone		—45	Manual, force pump	1–2	$\frac{1}{2}$	Domestic	
0	Sandy shale	Below Upper Kittanning coal			None		1	Roadside watering trough	Spring.
		Collar at Butler sandstone ±			Manual, force pump	2–3		Domestic	Slightly salty due to leakage from near by oil wells.
Near bottom	Shale	Mahoning sandstone	28		Manual, force pump	1–2	Ample	Domestic	Located at Woodbine village.
65	Sandy shale	Mahoning sandstone		—50	Manual, force pump	1–2	1	Domestic	
160	Coal	Upper Freeport coal					$1\frac{1}{2}$		
1,260	Sandstone	Hundred-foot sand					$\frac{1}{8}$		T. W. Phillips Gas & Oil Co. Salt water from each aquifer.
1,425	Sandstone	Nineveh sand					$\frac{1}{4}$		

No. on Fig. 36	Location: Nearest P. O.	Location: Distance and direction from P. O.	Owner or name	Topographic situation	Altitude above sea level	Depth of well	Diameter of well
					Feet	Feet	Inches
	Parker Township						
2	Parker's Landing	0	Miscellaneous	Terrace	1,100	20-30	----------
133[b]	Parker's Landing	0	----------	Hillside	950	0	----------
1001	North Washington	2 mi. E.	F. L. Kelly No. 1	Hillside	1,300	----------	----------
1002	Bruin	1¼ mi. NW.	A. E. Butler	Ridge crest	1,390	----------	----------
	Penn Township						
190[b]	Renfrew	2 mi. E.	----------	Hillside	1,130	0	----------
191[a]	Renfrew	2 mi. SE.	W. Fletcher	Upland	1,210	176	5-3/16
192[a]	Renfrew	2¼ mi. SE.	Philip Miller	Upland	1,220	105	6¼
	Portersville Borough						
3	Portersville	0	Dewdrop Inn	Upland	1,380	30	48
	Saxonburg Borough						
199	Saxonburg	0	Miscellaneous	Upland	1,280-1,320	100-160	----------

Chief aquifer: Depth below surface	Chief aquifer: Character of material	Chief aquifer: Geologic horizon	Depth to which well is cased	Water level above (+) or below (—) surface	Method of lift	Capacity of pump	Rate of inflow	Use of water	Remarks
Feet			Feet	Feet		Gallons per minute	Gallons per minute		
Near bottom	Sand and gravel	Glacial gravel	----------	----------	Manual, suction pumps	1-3	Ample	Domestic	Some dug wells.
0	Sandy shale	Burgoon sandstone	0	----------	None	----------	2	Drinking	Spring.
1,090	Sandstone	Hundred-foot sand	----------	----------	None	----------	1	----------	T. W. Phillips Gas and Oil Co. Salt water, cased off.
935	Sandstone	Hundred-foot sand	----------	----------	None	----------	1/25	----------	T. W. Phillips Gas and Oil Co. Salt water, cased off.
0	Sandy shale	Brush Creek coal±	----------	----------	None	----------	4-5	Roadside watering trough	Spring.
160	Shale	Brush Creek coal±	150	----------	Manual, force pump	1-2	Ample	Domestic	Located at Nixon Community.
Near bottom	Sandstone	Saltsburg sandstone	82	----------	Manual, force pump	1-2	Ample	Domestic	Located at Nixon Community.
Near bottom	Surficial rock waste	----------	----------	—25	Manual, force pump	2-3	Ample	Household and Inn	Dug well.
90-150	Coarse sandstone	Mahoning sandstone	90-100	—50 to 75	Manual, force pumps	1-3	Ample	Domestic	Also a few dug wells in surficial rock waste and drilled wells in sandy shale above the Mahoning sandstone.

No. on Fig. 36	Location: Nearest P. O.	Location: Distance and direction from P. O.	Owner or name	Topographic situation	Altitude above sea level	Depth of well	Diameter of well
					Feet	Feet	Inches
	Slippery Rock Township and Borough						
118	Slippery Rock	0	Slippery Rock Borough	Hilltop	1,435	365	6
119	Slippery Rock	0	Slippery Rock Borough	Hillside	1,325	375	10
120	Slippery Rock	0	Slippery Rock Borough	Valley	1,300	475	----------
121	Slippery Rock	0	State Teachers College	Hillside	1,250	300	6
122	Slippery Rock	0	State Teachers College	Hillside	1,310	200	6
123	Slippery Rock	0	State Teachers College	Hillside	1,320	275	6¼
124	Slippery Rock	2 mi. SE.	Oak Grove Dance Hall	Upland	1,280	102	----------
125	Branchton	1 mi. S.	B. & L. E. R. R.	Hillside	1,190	332	12
126[b]	Branchton	¾ mi. S.	----------	Valley	1,170	----------	6
	Summit Township						
173	East Butler	0	Valvoline Oil Co.	Valley	1,030	210	8
174	Butler	1½ mi. E.	Herman Pistorius	Ridge crest	1,270	151	----------
175	Herman	1½ mi. N.	Frank Birchbegler	Hillside	1,280	125	----------

Chief aquifer			Depth to which well is cased	Water level above (+) or below (—) surface	Method of lift	Capacity of pump	Rate of inflow	Use of water	Remarks
Depth below surface	Character of material	Geologic horizon							
Feet			Feet	Feet		Gallons per minute	Gallons per minute		
300	Sandstone	Homewood sandstone	----	—175	Electric, force pump	10	3½	Municipal supply	Two wells in pumphouse on top of hill in eastern part of borough.
225	Sandstone	Homewood sandstone	105	—80	Electric, force pump	10	7½	Municipal supply	----
313	Sandstone	Connoquenessing sandstone	----	----	----	----	----	----	Forty-foot sand.
210	Sandstone	Homewood sandstone	----	—80	----	----	36	Municipal supply	Well drilled in August, 1926, but not then equipped with pump.
300±	Sandstone	Connoquenessing sandstone	----	----	----	----	----	----	No water in lower part of Connoquenessing sandstone. Drilling suspended for fear of brackish water in the Burgoon sandstone.
Near bottom	Sandstone	Connoquenessing sandstone	----	----	Electric, force pump	----	8½	Domestic	----
Near bottom	Sandstone	Homewood sandstone	----	----	Electric, force pump	----	4–8½	Laundry	Water is not so hard as that from wells 121 and 123.
Near bottom	Sandstone	Connoquenessing sandstone(?)	----	----	Electric, force pump	----	16½	Domestic	----
Near bottom	Sandstone	Clarion sandstone	35	----	Manual, force pump	1–3	Ample	Drinking	----
80	Sandstone	Clarion sandstone	----	—40	----	----	?	Cased off	----
140	Sandstone	Pottsville or Burgoon (?) sandstone	185	—20	Gas engine, force pump	150	270	Locomotive boilers	Well at Branchton coal tipple. Specific capacity 67½ g. p. m. for each foot of drawdown in 30-hour pumpage test in 1917.
----	----	Pottsville or Burgoon (?) sandstone	----	+½	Natural flow	----	100	None	Abandoned gas well plugged at unknown depth.
126	----	Base of Vanport' limestone	----	----	Air lift	300	300	Condensers at oil refinery	Representative of 12 wells. Reported yield not checked.
190	Sandstone lentils	Homewood sandstone	----	----	----	----	----	----	----
Near bottom	Sandy shale	Freeport sandstone	----	—81	Manual, force pump	1–2	Barely adequate	Household	----
120	Sandstone and shale	Butler sandstone	----	----	Force pump	1–2	----	Domestic	No water locally in Upper Freeport coal.

No. on Fig. 36	Location: Nearest P. O.	Location: Distance and direction from P. O.	Owner or name	Topographic situation	Altitude above sea level	Depth of well	Diameter of well
					Feet	Feet	Inches
	Summit Township—Continued						
176	Herman	2 mi. NE.	Lawrence Graham	Ridge crest	1,290	87	6
177[a]	Herman	$\frac{1}{2}$ mi. W.	Edward Steighner	Upland	1,340	75	5
178	Herman	$\frac{1}{4}$ mi. W.	Monastery	Upland	1,335	317	$5\frac{5}{8}$
1007	Herman	$1\frac{1}{4}$ mi. E.	Christian Michal	Ridge crest	1,290	----------	----------
1008	Herman	1 mi. S.	Joseph Eichenlaub	Upland	1,340	----------	----------
	Valencia Borough						
215	Valencia	0	Grant Cox	Hillside	1,100	145	$6\frac{1}{4}$
	Venango Township						
109[b]	Clintonville	$\frac{1}{2}$ mi. W.	----------	Valley	1,260	----------	----------
110[b]	Boyers	$2\frac{3}{4}$ mi. NE.	----------	Hillside	1,330	0	----------
111	Deegan	0	Goff-Kirby Coal Co.	Hillside	1,250	116	$5\frac{5}{8}$
112	Clintonville	$2\frac{3}{4}$ mi. SE.	Mike Dokey	Ridge crest	1,490	188	----------
113	Eau Claire	$1\frac{1}{2}$ mi. NW.	Foster Sloan	Hillside	1,500	25	----------
116	Boyers	2 mi. E.	Keystone Coal Co.	Valley	1,275	200	$5\frac{5}{8}$

Chief aquifer			Depth to which well is cased	Water level above (+) or below (—) surface	Method of lift	Capacity of pump	Rate of inflow	Use of water	Remarks
Depth below surface	Character of material	Geologic horizon							
Feet			Feet	Feet		Gallons per minute	Gallons per minute		
82	Sandstone	Mahoning sandstone	------	—45	Manual, force pump	1–2	Ample	House-hold, service station	------
72	Red shale	Cambridge limestone±	------	—35	Manual, force pump	1–3	Ample	Household	------
Near bottom	Shale	Well penetrates Freeport sandstone±	165	—100	Manual, force pump	1–2	------	Domestic	Some water at about 75 feet, drained by crevices in shale at 160 feet, upper water cased off and well deepened. Two other wells similar to No. 177.
1,488	Sandstone	Hundred-foot sand	------	------	------	------	½	None	T. W. Phillips Gas & Oil Co. Salt water.
1,445 and 1,485	Sandstone	Hundred-foot sand	------	------	------	------	------	None	T. W. Phillips Gas & Oil Co. Salt water.
105	White sandstone	Buffalo sandstone	80	—105	Force pump	1–3	Ample	Household	Well at Lillian Rest near by, reported to yield 40 g. p. m. from Buffalo sandstone.
------	------	Homewood sandstone(?)	------	+Slight	Natural flow	------	5	None	Abandoned oil well plugged at uncertain depth. Located in Venango County.
0	Sandy shale	Above Clarion sandstone	------	------	Natural flow	------	2	Roadside trough	Spring.
Near bottom	(?)	Homewood sandstone(?)	60	Near surface	Force pump	1–3	------	Domestic	Iron-bearing water.
Near bottom	Shale	Above Clarion coal	150±	------	Force pump	1–3	------	Domestic	No water in Vanport limestone.
Near bottom	Weathered shale	Middle Kittanning coal±	------	------	Force pump	1–3	Very small	Domestic	Dug well. This and near by wells less than 50 feet deep were drained in 1920 by the drilling of a group of oil wells.
?	White sandstone	Kittanning or Clarion sandstone	------	------	------	------	Ample	Formerly domest'c	Well now abandoned. Located at Ferris.

No. on Fig. 36	Location: Nearest P. O.	Location: Distance and direction from P. O.	Owner or name	Topographic situation	Altitude above sea level	Depth of well	Diameter of well
					Feet	Feet	Inches
	Washington Township						
128	Argentine	0	Standard Coal Mining Co.	Valley	1,260	236	5⅝
129	Argentine	1¼ mi. SE.	Ross Sims	Hillside	1,470	103	5⅝
130	North Washington	0	Miscellaneous	Ridge crest	1,500	80–180	----------
	West Sunbury Borough						
137	West Sunbury	0	Miscellaneous	Upland	1,380–1,400	60–120	----------
	Winfield Township						
200	Marwood	¼ mi. W.	Standard Plate Glass Co.	Stream head	1,220	103	6¼
201	Marwood	⅓ mi. SW.	Fronek	Ridge crest	1,310	100	----------
202	Marwood	1¼ mi. E.	Harry Kennedy	Upland	1,350	93	6¼
203	Cabot	¾ mi. W.	J. Steignheizer	Upland	1,330	46	----------
204[b]	Cabot	0	H. P. Shearer	Valley	1,235	35±	----------
205[b]	West Winfield	1 mi. SW.	West Winfield village	Hillside	1,270	0	0
206	West Winfield	0	Pennsylvania Clay Products Co.	Valley	1,000	100±	----------
207	West Winfield	1¾ mi. S.	Flavius Denny	Hillside	1,200	151	4⅞

[a] Analysis of water made by U. S. Geological Survey.
[b] Flowing well or spring.

Chief aquifer			Depth to which well is cased	Water level above (+) or below (—) surface	Method of lift	Capacity of pump	Rate of inflow	Use of water	Remarks
Depth below surface	Character of material	Geologic horizon							
Feet			Feet	Feet		Gallons per minute	Gallons per minute		
225	Sandstone	Homewood sandstone	118		Force pump	1-3	Ample	Domestic	Well now abandoned. Iron-bearing water in Clarion sandstone cased off.
95	Yellow sandstone	Worthington sandstone			Gas engine, force pump				
Near bottom	Sandstone	Worthington and Kittanning sandstones			Manual, force pumps	1-3	Ample	Domestic	North Washington community. Deeper wells reach Kittanning sandstone. Some shallow wells drained by drilling deep oil wells.
Near bottom	Sandstone lentils	Freeport and Worthington sandstones			Force pumps	1-3	Ample	Domestic	Shallow wells yield iron-bearing water.
27	Shale	Brush Creek coal ±		—12	Force pump	25	25+	Cooling gas engines and compressors	Specific yield about 12½ g. p. m. for each foot drawdown.
97	White sandstone	Buffalo sandstone		-57	Force pump		Barely adequate	Domestic	Well not deepend from fear of iron-bearing water in coal. Iron-bearing water at 40 feet shut off by casing.
90	White sandstone	Mahoning sandstone	61	-57	Force pump	1-3	Ample	Domestic	Well at near by barn has very small yield.
Near base	Black shale	Bakerstown coal ±			Force pump	1-3	Ample	Domestic	
20	White sandstone	Mahoning sandstone		-2				Cooling	
30	Sandstone	Butler sandstone	25±	+Slight	Automatic electric, suction pump	3	3+	Household, lunchroom	
0	Sandstone	Mahoning sandstone			Natural flow		10-12	Village supply	Spring.
	Black sandstone	Brookville coal ±			Force pump	1-3	Ample	Domestic	
150	Sandstone	Mahoning sandstone	101	-126	Force pump	1-3	Ample	Domestic	

Driller's log of B. & L. E. R. R. Co.'s well at Harrisville station

(No. 101, Fig. 36.)

	Thickness (Feet)	Depth (Feet)
Sandy and clayey shale	55	0–55
Limestone (Vanport), water in bedding plane at 62 feeet	17	55–72
Sandstone	3	72–75
Ferruginous clay shale; iron-bearing water at 83 feet shut out by back-filling with cement to 75-foot level	10+	75–85

Driller's log of B. & L. E. R. R. Co.'s well at Branchton water station

(No. 125, Fig. 36.)

	Thickness (Feet)	Depth (Feet)
Surficial rock waste	48	0– 48
Sandy shale	21	48– 69
Sandstone (Clarion or Forty-foot)	51	69–120
Water at 80 feet, static level 50 feet below surface; water at 120 feet, static level 40 feet below surface		
Shale	20	120–140
Sandstone (Homewood, Connoquenessing (?), and Burgoon members without shale partings), water-bearing, static level 18 feet below surface	192	140–332

Driller's log of B. & L. E. R. R. Co.'s well at Queen Junction watering station

(No. 140, Fig. 36.)

	Thickness (Feet)	Depth (Feet)
Sandstone (Butler), small yield of water	35	0– 35
Fireclay	6	35– 41
Sandstone, gray	25	41– 66
Shale, dark	24	66– 90
Carbonaceous shale (Middle Kittanning coal?)	1	90– 91
Shale, gray	15	91–106
Coal (Lower Kittanning)	2	106–108
Shale, dark	32	108–140
Sandstone, white (Kittanning), water-bearing	24	140–164
Sandstone, gray	28	164–192
Shale, dark	10	192–202
Sandstone, white (Clarion)	20	202–222
Sandstone, dark gray (Homewood), water-bearing	20	222–242

Driller's log of Loyal Order of Moose well at Graham Station

(No. 161, Fig. 36.)

	Thickness (Feet)	Depth (Feet)
Alluvium	35	0– 35
Shale	3	35– 38
Sandstone (Buffalo, Bluff sand), water at 50 and 97 feet	59	38– 97
Shale	10	97–107
Limestone (Brush Creek), water at base	3	107–110
Shale	18	110–128

Note. Iron-bearing or "red" water in alluvium at 25 feet was cased off.

Driller's log of W. G. Douthett well at Boulevard

(No. 163, Fig. 36.)

	Thickness (Feet)	Depth (Feet)
Rock waste	30	0– 30
Shale, with thin sandstone lentils	160	30–190
Coal (Mahoning), not water-bearing	4	190–194
Shale, water at 210 feet, yield 2½ gallons per minute	46	194–240
Coal (Upper Freeport), not water-bearing	4	240–244
Shale, very small yield of water	46	244–290
Coal (Lower Freeport)	4	290–294
Shale	46	294–340
Coal (Upper Kittanning)	4	340–344
Shale	131	344–475
Limestone (Vanport)	12	475–487
	33	487–520
Sandstone (Clarion or Sixty-foot), yield of water is less than 1½ g. p. m.	30	520–550

Driller's log of Citizen's Mutual Water Co.'s No. 8 well at Butler

(No. 166, Fig. 36.)

	Thickness (Feet)	Depth (Feet)
Rock waste	10	0– 10
"Limestone" (Butler sandstone?)	25	10– 35
Coal (Lower Freeport?)	2	35– 37
Shale	18	37– 55
Sandstone, gray	5	55– 60
Shale	18	67– 78
Coal (Upper Kittanning?)	4	78– 82
Fireclay	5	82– 87
Sandstone, gray	8	87– 95
Shale	35	95–130
Coal	4	130–134
Shale	50	134–184
Coal	6	184–190
Shale	7	190–197
Sandstone (Kittanning), white, water at 205 feet	35	197–232
Shale	8	232–240
Limestone (Vanport)	15	240–255
Sandstone (Clarion and Homewood), white, water-bearing	105	255–360
Shale	37	360–397

Driller's logs of Evans City Borough wells

(No. 183, Fig. 36.)

	Thickness (Feet)	Depth (Feet)
No. 1 well:		
Rock waste	12	0- 12
Sandstone	30	12- 42
Shale	57	42- 99
Coal (Lower Kittanning)	3	99-102
Fireclay	3	102-105
Limestone	9	105-114
Shale	28	114-142
Coal	2	142-144
Fireclay	4	144-148
Limestone	9	148-157
Sandstone (Clarion)	3	157-160
Shale with thin sandstone lentils	91	160-251
Sandstone (Homewood), white, water-bearing	18	251-269
No. 2 well:		
Sandstone (Worthington), water at 185 feet, yield 1 g. p. m.	20	175-195
brackish water at 225 feet, seepage from oil well nearby	56	195-251
Sandstone (Homewood) white, water-bearing	29	251-280
Shale (Mercer?)	25	280-305
Sandstone (Connoquenessing?)	4	305-309
Shale, black and gritty at top, gray at base	24	309-333
Coal (Sharon), salt water, plugged off	6	333-339
Fireclay	----------	339-

Note. Wells drilled in July, 1923.

Driller's log of B. & L. E. R. R. Co.'s well at Houseville watering station

(No. 219, Fig. 36.)

	Thickness (Feet)	Depth (Feet)
Soil	2	0- 2
Sandstone (Buffalo)	48	2- 50
Shale, dark	23	50- 73
Coal (Brush Creek?)	1	73- 74
Fireclay	48	74-122
Limestone	2	122-124
Sandstone (Mahoning)	14	124-138
Shale, light	6	138-144
Coal (Upper Freeport)	1	144-145
Shale, dark	7	145-152
Limestone (Upper Freeport)	9	152-161

Note. Well drilled in October, 1909.

FAYETTE COUNTY

TOPOGRAPHY AND DRAINAGE

Fayette County, which occupies the southeastern portion of the area covered by this report, (See Fig. 1), is divisible into two physiographic districts by a line which trends N.35°E. from a point about 3 miles east of Cheathaven and, following the western flank of Chestnut Ridge, passes 2½ miles east of Uniontown and along the eastern edge of Connellsville Borough. To the west of this line lies the Kanawha section of the Appalachian Plateaus; to the east is a nearly equal area which is a part of the Allegheny Mountains section (p. 12). The Kanawha section, at a distance from the major streams, is an assemblage of sub-

mature rounded hills and ridges and open valleys of rounded contour. The summit elevations are only approximately accordant, and, from a maximum of 1,565 feet above sea level at Fort Hill—about 5½ miles west of Scottdale—in the north central part of the district, decline westward to 1,250 to 1,400 feet above sea level along the Monongahela Valley and southward to a minimum of 1,200 to 1,300 feet above sea level at the boundary between Pennsylvania and West Virginia. The local relief is 200 to 350 feet. The major streams, however, occupy youthful trenches which are cut 400 to 600 feet below the ridge crests. The minimum elevation in this portion of the county, in the Monongahela Valley, is approximately 730 feet above sea level, so that the extreme relief is 835 feet. The Allegheny Mountains section comprises two bold strike ridges—Chestnut Ridge on the west and Laurel Hill on the east—and an intermontane valley some miles in width. The two ridges trend N.30°E. entirely across the county and, in the distance of 28 miles, are pierced only by Youghiogheny River. Chestnut Ridge is highest, 2,780 feet above sea level, in a knob about 4 miles southeast of Fairchance, thence declines gradually northward to less than 2,000 feet above sea level at the boundary of the county. Laurel Hill ranges in elevation from 3,010 feet to 2,685 feet above sea level in the region north of Youghiogheny River. The intermontane area is an intricately dissected sub-mature terrane whose summits range from 1,850 to 2,200 feet above sea level and whose drainage ways are cut to an altitude of 1,250 to 1,600 feet above sea level. The greatest local relief within this portion of the county is approximately 1,625 feet at the Youghiogheny River gap through Laurel Hill. The extreme relief for the entire county is approximately 2,280 feet.

Fayette County is bounded on the west by the Monongahela River and is transsected from southeast to northwest by Youghiogheny River. These major streams of the area receive the drainage from the Kanawha section by numerous westward-flowing tributaries, among which are Jacobs Creek, Redstone Creek, Dunlap Creek, Browns Run, and George Creek. Cheat River joins the Monongahela from the southeast about 2 miles north of the Pennsylvania-West Virginia boundary. The northern three quarters of the Allegheny Mountains section is drained into Youghiogheny River by subsequent tributaries, Indian and Beaver creeks. The southern portion of the district is drained southward into Cheat River by another subsequent stream, Sandy Creek.

AREAL GEOLOGY

The sedimentary rocks which crop out in Fayette County (see Pl. I) range in age from basal Pocono on the east to uppermost Washington on the west, the composite stratigraphic column having an average thickness of about 3,000 feet. The column is interrupted by one major break, the regional unconformity between the Mauch Chunk and Pottsville formations. Full sections of the Allegheny, Conemaugh, and Monongahela formations are exposed. The sedimentary rocks are overlain in the major stream valleys by unconsolidated deposits of the Carmichaels formation and of alluvium. These deposits are relatively limited in extent, however. The youngest of the consolidated sediments, the topmost beds of the Washington formation, cap the highest summits in the deepest part of the Lambert syncline (see Pl. I) about 2½ miles southeast of the village of Merrittstown. The oldest crop out in

the Youghiogheny River gap through Laurel Hill, about 3½ miles east of Ohiopyle. The Washington formation crops out over an extensive area in the Lambert syncline and forms separated hilltop caps northward to and beyond the boundary of the county and westward across the axis of the Brownsville anticline. Farther east it occupies the deepest part of the Uniontown trough as much as 3 miles south of Uniontown borough.

The underlying Monongahela formation covers virtually all the lower portion of the terrane west of the Fayette anticline, forms a peripheral band about the deeper part of the Uniontown syncline, and caps the highest ridges of the Kanawha section southward to the State boundary. The subjacent Conemaugh beds crop out in an irregular serrate band 2 to 6 miles wide along the crest of the Fayette anticline and in a parallel but narrower band along the flank of the Uniontown basin farther east. To the north these bands are joined in the Jacobs Creek valley; to the south they merge in the valleys of Monongahela and Cheat rivers as well as George Creek. Small outcrops occur also in the Monongahela Valley at the northwestern corner of the county, in the lower valley of Dunlap Creek at Brownsville, and in the Cats Creek basin south of Masontown. Farther east, in the Allegheny Mountain section, the formation caps the principal ridges of the Indian Creek valley, covers most of the intermontane basin southwest of Youghiogheny River, and crops extensively in the Youghiogheny Valley about Somerfield. Within the Kanawha section the underlying Allegheny and Pottsville rocks are exposed only on the crest of the Fayette anticline in the valleys of Jacobs Creek and the Youghiogheny River. The principal outcrop areas of the Allegheny and of the subjacent formations, however, are in the Allegheny Mountains section farther east, each of these stratigraphic units forming a most sinuous band along the flanks or across the crests of the Chestnut Ridge and Laurel Hill anticlines.

GEOLOGIC STRUCTURE

The consolidated sediments of Fayette County are deformed by a number of sub-parallel folds, the strike of whose axes is usually N.30°E. although the range is N.15-40°E. These are shown on an accompanying map (Pl. I) by contour lines drawn as though on the base of the Pittsburgh coal. In the extreme western part of the county is the Brownsville anticline, which has an ill-defined undulating crest and gentle transverse dips. To the east lies the Lambert syncline, an asymmetric structure which is a virtual continuation of the Port Royal syncline of Westmoreland County. Its axis, which crosses the Monongahela Valley 3 miles north of Masontown and terminates at a point 2 miles west of Perryopolis, divides the county into two structural provinces, which are southward continuations of similar features in Westmoreland County. The eastern of these two provinces is characterized by folds which are notably closer and deeper. At its western edge is a group of three symmetrical canoe-shaped folds arranged en echelon, the points of greatest amplitude of deformation falling on a line which trends approximately due north and south. These are, in succession from the northwest, the Fayette anticline, Uniontown syncline, and Dulany anticline. Within this group, the index horizon descends to a minimum altitude of 530 feet above sea level in the Uniontown trough and attains a maximum of 4,200 feet above sea level on the Dulany

crest. This amplitude of folding, 3,670 feet, is a maximum for the entire region covered by the investigation. The greatest dip of the beds is 12½°. Still farther east, the principal folds—Chestnut Ridge anticline, Ohiopyle syncline, Laurel Hill anticline, and Youghiogheny syncline—have a more pronounced linear aspect, somewhat gentler dips, and a lesser amplitude. Inasmuch as the post-Mauch Chunk beds are conformable throughout and have been similarly folded, it follows that the deformation of any given water-bearing stratum is similar to that of the index bed and, consequently, may be read directly from the map (Pl. I). Further, the angular discordance between the post-Mauch Chunk and the older formations is so slight that the difference in elevation of any water-bearing member of the pre-Pottsville rocks between adjacent well sites departs from that of the index bed by an amount which is less than the limit of discrimination on the map. Consequently the map can be employed without appreciable error.

GROUND WATER RESOURCES

General features

In consequence of its great thickness of exposed rocks, its great topographic relief, and the amplitude of folding, Fayette County discloses a very wide range of ground water conditions. In the Kanawha section the springs are few and small, and most household water supplies are derived from drilled wells. Although few wells are wholly unsuccessful it is impossible in many districts in which the rocks are dominantly shaly, to develop supplies of fresh water of more than 5 gallons per minute. Within this district salty waters may be found at depths exceeding 250 feet and it is unlikely that anything other than highly concentrated brines occur at depths of 500 feet or more. However, the static level of the salt water is usually far below that of the fresh water aquifers so that contamination of the potable supplies is not to be expected. In the Monongahela and Youghiogheny valleys, however, saline waters are likely to be found within 100 feet of the surface, as in well 594 of South Brownsville Borough (Fig. 37 and p. 304). So far as known, fresh water does not exist in any stratum beneath the uppermost salt water aquifer. In the Allegheny Mountains section on the other hand, the great topographic relief, coupled with the relatively large amplitude of folding, has exposed a thick succession of permeable beds. On the slopes of the major ridges these beds are usually saturated with water which is in transit downward, and supply a very large number of springs, many of which are of fourth magnitude. Hence the problems of water supply are not acute. In the intermontane areas, springs are locally abundant and fewer wells have been drilled than in the less rugged Kanawha section, although many potential aquifers exist. Moreover, the ground waters of the Allegheny Mountains section are fresh even where they exist below drainage level.

Those stratigraphic units which are known to be sources of fresh water supplies within the county are listed in the subjacent table with references to the pages on which the water-bearing properties of each are discussed at length. Of these the sandstone members are outstanding. In other types of rock, ground water occurs in bedding plane conduits of small magnitude where the beds are not deeply buried,

but is not usually obtainable where the beds pass beneath thick continuous cover.

The chemical character of the ground waters is shown by the analyses of representative samples which are tabulated on pages 80-81, and is treated further in the descriptions of the several water-bearing members. Artesian conditions exist in the more deeply folded rocks of the eastern portion of the county and are described on pages 68-69.

Sources of fresh water in Fayette County

Formation and member	Pages of this report
Washington formation:	
Washington sandstone	140
Waynesburg sandstone	141
Monongahela formation:	
Waynesburg coal and associated beds	146
Waynesburg limestone	146
Uniontown sandstone	147
Uniontown and Benwood limestones	148
Sewickley sandstone	151
Fishpot limestone	152
Redstone limestone	153
Pittsburgh sandstone	154
Conemaugh formation:	
Pittsburgh limestones	157
Connellsville sandstone	159
Clarksburg limestone	160
Morgantown sandstone	163
Duquesne coal and associated rocks	169
"Pittsburgh Reds"	169
Saltsburg sandstone	170
Bakerstown coal	174
Buffalo sandstone	175
Mahoning sandstone	178
Allegheny formation:	
Butler sandstone	184
Freeport sandstone	186
Worthington sandstone	187
Lower Kittanning clay and associated beds	189
Kittanning sandstone	189
Pottsville formation:	
Homewood sandstone	193
Connoquenessing sandstone	196
Pocono formation:	
Burgoon sandstone	198
Murrysville sand	201

Although coal mining has been carried on extensively in the Uniontown basin for many years, the supporting pillars and ribs have not been removed over most of the area so that the roof rocks are intact. Consequently, the beds of the Washington and Monongahela formations retain their normal water-bearing properties but, being for the most part above drainage level, are uncertain source beds of small water-yielding capacity. Locally, however, some subsidence of the roof has occurred and failure of wells and springs has resulted from drainage of the water-bearing beds. The rocks which underlie the coal yield little or no water where they lie beneath continuous cover, a fact which has made it difficult to obtain adequate water supplies at many mining communities and has led to the construction of an extensive system of mains for the distribution of surface water.

Municipal supplies

Dawson.—The borough of Dawson (population 800), on the north bank of Youghiogheny River, draws its water supply from two wells (No. 572, Fig. 37 and p. 294) on a river terrace remnant at the northern edge of the borough, and from three wells at the former driving

park half a mile to the northeast. The two wells within the borough are 140 feet and 160 feet deep, respectively, and reach the Morgantown sandstone slightly above the level of the Youghiogheny River. These wells are equipped with electrically driven deep well force pumps which discharge into a 500,000-gallon distribution reservoir nearby. Two of the three wells to the northeast are also equipped with electrically driven Hill deep well force pumps, rated capacity 30 gallons per minute each, which discharge through 4-inch force mains into the reservoir. Distribution is by gravity through a 6-inch main 3,000 feet long. Between one-third and one-half of the population is supplied, the average daily consumption being somewhat less than 10,000 gallons.

Uniontown. The municipality of Uniontown (population 19,544) obtains the major portion of its water supply from a number of impounding reservoirs on the headwater tributaries of Redstone Creek along the eastern flank of Chestnut Ridge. A small part of the supply is contributed by Cool Spring (No. 606), which is on the southern branch of Shutes Run. This spring issues from jointed and weathered Connoquenessing sandstone. The spring orifice is walled with rubble masonry, laid without mortar, and is protected from the influx of surface water by concrete cut-off walls and cover. A 4-inch overflow pipe 100 feet long discharges by gravity into the nearby impounding reservoir. The yield of the spring is variable, the seasonal minimum being about 100 gallons per minute except during extreme drought. Consequently the spring is of fourth magnitude. The quality of the water is shown by analysis 606 (see p. 81).

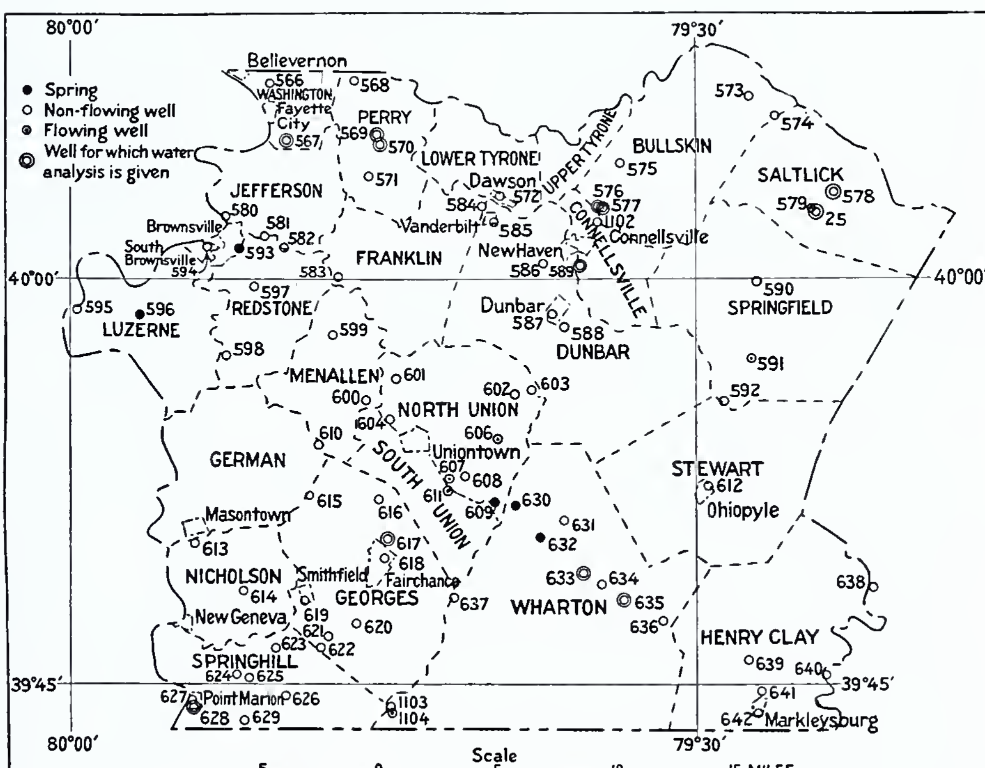


Figure 37. Map of Fayette County showing location of wells and springs described in this report.

TYPICAL WELLS AND SPRINGS IN FAYETTE COUNTY, PA.

No. on Fig. 37	Location: Nearest P. O.	Location: Distance and direction from P. O.	Owner or name	Topographic situation	Altitude above sea	Depth of well	Diameter of well
					Feet	Feet	Inches
	Brownsville Township and Borough						
593[b]	Brownsville	1 mi. E.	------------	Hillside	900	0	------
	Bullskin Township						
573	Acme	2 mi. SW.	David Kinneer	Hillside	2,150	62	4¼
574	Acme	2 mi. S.	Mount Zion Church	Ridge crest	1,985	62	4¼
575	Pennsville	¼ mi. E.	Emmett Hatfield	Hillside	1,100	115	5⅝
576[a]	Connellsville	1¾ mi. NE.	J. E. Henderson	Valley	950	40	5⅝
577[a]	Connellsville	1¾ mi. NE.	Charles Balsley	Valley	950	100±	5⅝
	Connellsville Township and Borough						
589[a]	Connellsville	Pittsburgh Street	Yough Brewing Co.	Valley	910	150	8
1102	Connellsville	1¼ mi. NE.	Jess Barnes	Hillside	975	2,300	------
			Jess Barnes	Hillside	975	2,300	13–8
	Dawson Borough						
572	Dawson	½ mi. N.	Dawson Borough	Terrace	1,025±	140–160	------
	Dunbar Township and Borough						
586	Connellsville	2 mi. SW.	H. C. Frick Coke Co.	Valley	970	315	20
587	Dunbar	0	Boyer	Hillside	1,050	115±	5⅝
588	Dunbar	1½ mi. SE.	Dunbar Borough	Valley	1,025	------	------

[a] Analysis by U. S. Geological Survey.
[b] Flowing well or spring.

Chief aquifer: Depth below surface	Chief aquifer: Character of material	Chief aquifer: Geologic horizon	Depth to which well is cased	Water level above (+) or below (—) surface	Method of lift	Capacity of pump	Rate of inflow	Use of water	Remarks
Feet			Feet	Feet		Gallons per minute	Gallons per minute		
0	Limestone	Benwood limestone	------	------	Natural flow	------	3	Roadside trough	Spring.
62	Base of limestone	Vanport limestone	11	—50	Manual, force pump	1–3	5+	Domestic stock	------
62	Sandstone	Pottsville formation	18	—31	Manual, force pump	1–3	Ample	Drinking	------
Near base	Sandy shale	Above Morgantown sandstone	25±	—40±	Manual, force pump	1–3	Ample	Domestic	------
Near base	Sandstone and shale	Connellsville sandstone±	20	—3	Manual, force pump	1–3	Ample	Domestic	Coalbrook community.
Near base	Shale	Morgantown sandstone	40±	—20	Manual, force pump	1–3	Small	Domestic	Coalbrook community.
100±	Shale (?)	Saltsburg sandstone	30	—50	Steam, force pump	25	25+	Condensers bottling	Specific capacity about 1/3 g. p. m. per foot drawdown.
40	Sandstone lentil	Connellsville sandstone	------	—10	Force pump	------	5+	Domestic	Map location uncertain
317	Sandstone	Saltsburg sandstone	------	------	None	------	------	None	Abandoned gas well. Fresh water.
1,300	Sandstone	Burgoon sandstone	------	------	------	------	------	------	Fresh water reported.
2,150	Sandstone	Murrysville or Fifty-foot sand	------	------	------	------	10±	------	Fresh water reported.
------	------	Morgantown sandstone (?)	------	------	Force pump	30	------	Municipal supply	Two wells within borough, three wells at old driving park 1,500 feet north.
45	Limestone	Uniontown limestone	------	—15	None	------	Large	------	Bore hole into Trotter mine. Approximately located.
Near bottom	Sandy shale	Saltsburg sandstone	40	—50	Manual, force pump	1–3	Ample	Domestic	------
------	------	Pottsville formation (?)	------	------	Air lift	------	------	------	Former municipal supply, in part, from 5 wells.

No. on Fig. 37	Location: Nearest P. O.	Location: Distance and direction from P. O.	Owner or name	Topographic situation	Altitude above sea	Depth of well	Diameter of well
					Feet	Feet	Inches
	Fairchance Borough						
618	Fairchance	½ mi. NE.	Quertinmont Glass Co.	Valley	1,085	212	10-8
	Franklin Township						
583	Smock	½ mi. N.	Franklin Township Water Co.	Hillside	925	----------	----------
584	Dickerson Run	½ mi. S.	Dickerson Run Water Co.	Hilltop	975	104	----------
	Georges Township						
615	Brownfield	5 mi. W.	Georges Coal Co.	Upland	1,200	400 max.	----------
616	Brownfield	2 mi. W.	Stenson & McGrail	Upland	1,250	90 and 120	5⅝
617[a] [b]	Fairchance	1¼ mi. NE.	H. C. Frick Coke Co.	Valley	1,075	165	5⅝
620	Smithfield	2½ mi. SE.	Haydentown School	Hillside	1,125	80	5⅝
621	Smithfield	1¾ mi. SE.	Ruble School	Valley	1,010	83	5⅝
622	Smithfield	2 mi. S.	Frank King	Hillside	1,090	54	5⅝
	German Township						
610	Uniontown	4 mi. W.	Homer Saxon	Upland	1,225	85	5⅝
			Thompson, No. 1	----------	----------	2,907	----------

Chief aquifer: Depth below surface	Chief aquifer: Character of material	Chief aquifer: Geologic horizon	Depth to which well is cased	Water level above (+) or below (—) surface	Method of lift	Capacity of pump	Rate of inflow	Use of water	Remarks
Feet			Feet	Feet		Gallons per minute	Gallons per minute		
160	Sandstone	Saltsburg sandstone	----------	—12	Electric, suction pump	35	50(?)	Industrial	Specific capacity about $7\frac{1}{2}$ g. p. m. for each foot drawdown.
----------	----------	Conemaugh formation	----------	----------	----------	----------	----------	Domestic, fire protection	Two wells at Colonial No. 1 mine, H. C. Frick Coke Co.
Near bottom		Morgantown sandstone (?)	----------	----------	Force pump	20±	----------	Public supply	New Dickerson Run community.
----------	None	----------	----------	----------	None	----------	None	----------	About 20 wells above Highhouse village, base of deepest reaches Ames limestone ±. Dry holes.
Near bottom	Limestone	Waynesburg or Uniontown limestone	20	—45±	Windmill and manual, force pumps	1-5	½±	Domestic greenhouse	Located at Chadville village.
150	Sandstone	Morgantown sandstone	150±	+5	Natural flow	----------	200±	Household	Wynn plant.
65	Shale	Below Saltsburg sandstone	20±	—30	Manual, force pump	1-3	Ample	Drinking	----------
Near bottom	Shale	Duquesne coal ±	20±	—30±	Manual, force pump	1-3	Ample	Drinking	----------
Near bottom	Limestone	Clarksburg limestone	15	—40±	Manual, force pump	1-3	5+	Domestic	----------
Near base	Sandstone	Morgantown sandstone	----------	—35	Manual, force pump	1-3	5+	Domestic	Balsinger village.
1,310 1,740	Sandstone Sandstone	Homewood sandstone Burgoon sandstone	----------	----------	None	----------	----------	None	----------

No. on Fig. 37	Location: Nearest P. O.	Location: Distance and direction from P. O.	Owner or name	Topographic situation	Altitude above sea	Depth of well	Diameter of well
					Feet	Feet	Inches
	Henry Clay Township						
638	Confluence	0	Confluence Ice Co.	Stream plain	1,330	200±	$5\frac{5}{8}$
639	Markleysburg	2 mi. N.	Rendine Bros.	Hillside	2,350	120	$6\frac{1}{4}$
640	Somerfield	0	Miscellaneous	Hillside	1,390±	70±	$6\frac{1}{4}$
641	Markleysburg	$\frac{3}{4}$ mi. N.	Ewing Glover	Hillside	1,925	35	$5\frac{5}{8}$
	Jefferson Township						
580	Brownsville	$1\frac{1}{2}$ mi. N.	Albany Coal Co.	Valley	800	99	$5\frac{5}{8}$
581	Braznell	0	Pittsburgh and Erie Coal Co.	Valley	800	250	6
582	Grindstone	0	Rocks	Valley	900	127	$5\frac{5}{8}$
	Luzerne Township						
595	Millsboro	$\frac{1}{2}$ mi. S.	Huston Coal and Coke Co.	Valley	875	75	$5\frac{5}{8}$
596[b]	Merrittstown	3 mi. W.	----------	Hillside	1,090	0	----------
	Markleysburg Borough						
642	Markleysburg	$\frac{1}{4}$ mi. SE.	Walter Meyers	Stream head	1,975	40	$5\frac{5}{8}$

Chief aquifer			Depth to which well is cased	Water level above (+) or below (—) surface	Method of lift	Capacity of pump	Rate of inflow	Use of water	Remarks
Depth below surface	Character of material	Geologic horizon							
Feet			Feet	Feet		Gallons per minute	Gallons per minute		
Near base	----------	Homewood sandstone (?)	125	—40	----------	120	----------	Condensers ice plant	Located in Somerset County.
80	Sandstone	Buffalo sandstone	12	—20	Electric, suction pump	----------	Ample	Domestic	Located at Elk Park.
----------	Sandstone	Freeport sandstone	----------	—12±	Manual, suction pumps	1–3	Ample	Domestic	Village of Somerfield, Somerset County.
35	Top of sandstone	Butler sandstone ±	10±	—10	Manual, suction pump	1–3	1—	Domestic	----------
79	Shale	Lower Pittsburgh limestone ±	65±	—30	Manual, force pump	1–3	5+	Domestic	Company dwellings and store.
110	Soft shale	Little Pittsburgh coal ±	140	—65	None	----------	See note	None	Aggregate yield reported as 50 g. p. m. Water from 110-foot and 130-foot aquifers is fresh.
130	Shale	Lower Pittsburgh limestone ±							
210	Sandstone	Morgantown sandstone							
Near base	Coarse sandstone	Sewickley sandstone	16	—75	Manual, force pump	1–3	¼	Domestic	Salt water.
Near base	Shale	Fishpot limestone ±	35	—20±	Manual, force pump	1–3	½±	Domestic	----------
0	Sandstone	Waynesburg sandstone	----------	----------	Natural flow	----------	1	Roadside trough	Spring.
35	Top of sandstone	Mahoning sandstone	----------	—15	Manual, suction pump	1–3	2±	Domestic	----------

No. on Fig. 37	Location		Owner or name	Topographic situation	Altitude above sea	Depth of well	Diameter of well
	Nearest P. O.	Distance and direction from P. O.					
					Feet	Feet	Inches
	Menallen Township						
599	Upper Middletown	1¾ mi. W.	Lincoln Coal & Coke Co.	Valley	1,075	460	8
600	Uniontown	2⅓ mi. NW.	Crossland	Hillside	1,110	120	6¼
	Uniontown	3 mi. NW.	Dearth	----------	----------	----------	----------
	Nicholson Township						
613	Masontown	¾ mi. S.	Bessemer Coke Co.	Hillside	900±	70	5⅝
614	Smithfield	2¾ mi. W.	Samuel Mosier	Hillside	1,175	140	5⅝
	North Union Township						
601	Oliver	1⅓ mi. NW.	Charles Smith	Upland	1,200	183	5⅝
602	Mount Braddock	1¼ mi. S.	Ralph Raymond	Valley	1,350	35±	5⅝
603	Mount Braddock	1⅓ mi. SE.	Andrew Povlock	Hillside	1,800±	98	5⅝
604	Uniontown	1¼ mi. NW.	J. V. Thompson	Hilltop	1,200	125	6¼
605	Uniontown	1¼ mi. NW.	J. V. Thompson	Hilltop	1,200	1,100	14–10
606[a] [b]	Lemont Furnace	1¼ mi. SE.	Cool Spring	Valley	1,275	0	----------
607[b]	Hopwood	0	Abe Moore	Valley	1,150	260	6¼
608	Hopwood	¾ mi. E.	John Wheeler	Valley	1,225	35	5⅝
609[b]	Hopwood	2 mi. SE.	Second Watering Trough	Hillside	2,500±	0	----------

Chief aquifer			Depth to which well is cased	Water level above (+) or below (—) surface	Method of lift	Capacity of pump	Rate of inflow	Use of water	Remarks
Depth below surface	Character of material	Geologic horizon							
Feet			Feet	Feet		Gallons per minute	Gallons per minute		
450	Sandstone	Buffalo sandstone	30	—50	Steam, force pump			Domestic, industrial	No water in strata above the Saltsburg sandstone.
100	Sandstone	Morgantown sandstone	40	—30	Manual, force pump	1-3	Ample	Household	
591	Sandstone	Freeport sandstone (?)			None			None	
Near base	Shale	Above Little Pittsburgh coal	16	—20	Manual, force pump	1-3	20+	Abandoned	Former domestic supply at Griffin No. 1 mine.
Near base	Sandstone (?)	Pittsburgh sandstone	57	—115	Manual, force pump		1/5±	Domestic	Village of Old Frame.
120	Sandstone	Pittsburgh sandstone	80	—60			⅛		Inadequate for dairy, not developed.
30	Shale and sandstone	Mahoning sandstone		—12	Manual, suction pump	1-3	10+	Domestic	
Near base	Base of fire-clay	Lower Kittanning clay ±		—30	Manual, force pump	1-3	½	Domestic	
Near base	Sandy shale	Uniontown sandstone ±	20±	—30	Manual, force pump	1-3	10+	Domestic	Abandoned.
1,080	Sandstone	Kittanning sandstone	250	—800±	None		5+	None	Salt water. Located near No. 604. Conemaugh formation dry.
0	Sandstone	Connoquenessing sandstone			Natural flow		100±	Uniontown municipal supply in part	
175	Sandstone	Mahoning sandstone	10	+8±	Manual, suction pump	1-3	Ample	Domestic	
35	Sandstone	Connoquenessing sandstone	25	—5	Manual, suction pump	1-3	Ample	Domestic	
0	Sandstone	Burgoon sandstone			Natural flow		100±	Highway service station	Spring.

No. on Fig. 37	Location: Nearest P. O.	Location: Distance and direction from P. O.	Owner or name	Topographic situation	Altitude above sea	Depth of well	Diameter of well
					Feet	Feet	Inches
	Ohiopyle Borough						
612	Ohiopyle	0	William Glotfelty	Valley	1,225	115	$5\frac{5}{8}$
	Perry Township						
568	Wickhaven	0	Oliver Heilman	Valley	950	60	$5\frac{5}{8}$
569[a]	Perryopolis	0	John Armstrong	Hilltop	1,020	80	$5\frac{5}{8}$
570[a]	Perryopolis	$\frac{1}{3}$ mi. S.	Jack Flannagan	Valley	975	130	$4\frac{1}{4}$
571	Starjunction	$\frac{1}{4}$ mi. NE.	Washington Coal & Coke Co.	Hillside	1,025±	60–120	$5\frac{5}{8}$
	Point Marion Borough						
627	Point Marion	0	A. S. Maple	Stream plain	810	48	$5\frac{5}{8}$
628[a]	Point Marion	$\frac{1}{2}$ mi. S.	Point Marion Ice Co.	Valley	820	300	$7\frac{5}{8}$
	Redstone Township						
597	Merrittstown	$2\frac{1}{2}$ mi. NE.	C. C. Hilderbrand	Hilltop	1,225	220	$6\frac{1}{4}$
598	Merrittstown	$1\frac{1}{2}$ mi. SE.	Hillman Coal & Coke Co.	Hillside	1,000±	200±	$6\frac{1}{4}$
			H. J. Moore	----------	----------	1,983+	----------
	Saltlick Township						
25[a]	Melcroft	$1\frac{1}{4}$ mi. SW.	Sam Kalp	Valley	1,425	26	48±
578[a]	Melcroft	0	Melcroft Coal Co.	Valley	1,425	58	$4\frac{1}{4}$
579	Melcroft	$1\frac{1}{4}$ mi. SW.	Sam Kalp	Hillside	1,465±	200±	$5\frac{5}{8}$

Chief aquifer			Depth to which well is cased	Water level above (+) or below (—) surface	Method of lift	Capacity of pump	Rate of inflow	Use of water	Remarks
Depth below surface	Character of material	Geologic horizon							
Feet			Feet	Feet		Gallons per minute	Gallons per minute		
Near base	Shale	Connoquenessing sandstone ±	50		Manual, force pump	1–3	Ample	Domestic	
Near base	Sandstone lentil	Sewickley sandstone		—25	Manual, force pump	1–3	Ample	Domestic	
	Soft shale	Clarksburg limestone	35	—40	Manual, force pump	1–3	5±	Domestic	
	Shale (?)	Morgantown sandstone ±	90	—20±	Automatic electric, force pump	3	5+	Domestic	Hard water at depth 80 feet cased off.
Near bottom	Shale	Above Morgantown sandstone	18±	—90 max.	Manual, force pump	1–3	3±	Domestic	Eleven wells at company dwellings.
40	Shale	"Pittsburgh Reds"	38±	—20	Manual, suction pump	1–3	5+	Domestic	
165	Sandstone	Saltsburg sandstone	20	—15	Air lift	50	50+	Condensers	Specific capacity about 5 g. p. m. per foot drawdown.
Near bottom	Sandstone	Washington sandstone		—70	Manual, force pump	1–3	1±	Domestic	Village of Davidson.
	Limestone	Uniontown limestone	100+	—30	Manual, force pump	1–3		None	Salt water reported; well not equipped.
228	Coal	Waynesburg coal			None			None	
660	Sandstone	Connellsville sandstone							
	Sand and gravel	Alluvium		—20	Automatic electric, suction pump	3	Ample	Domestic	Dug well. Village of Davistown.
46	Black sandstone	Worthington sandstone	25	—12±	Manual, force pumps	1–3	5+	Domestic	Company dwellings. Iron-bearing water.
Near base	Sandy black shale	Worthington sandstone	160	—80	Manual, force pump	1–3	Ample	Domestic	Village of Davistown.

No. on Fig. 37	Location: Nearest P. O.	Location: Distance and direction from P. O.	Owner or name	Topographic situation	Altitude above sea level	Depth of well	Diameter of well
					Feet	Feet	Inches
	Smithfield Borough						
619	Smithfield	0	John L. Everly	Upland	1,125	140	5⅝
	South Brownsville Borough						
594	South Brownsville	0	Rice Bros. Laundry	Valley	760	240	10-8
	South Union Township						
611[b]	Hopwood	½ mi. SE.	Nick Cornish	Valley	1,190	30	6¼
	Springfield Township						
590	Normalville	0	Earl Brooks	Ridge crest	1,690	70	5⅝
591[b]	Mill Run	0	Mrs. A. C. Stickel	Valley	1,360	35±	5⅝
592	Mill Run	2 mi. SW.	Erwick	Valley	1,125	100±	5⅝
	Springhill Township						
623	Gans	2 mi. N.	Morgan Grove	Hillside	1,090	100	5⅝
624	Gans	2¼ mi. NW.	T. S. Gans	Upland	1,115	40-60	5⅝
625	Gans	1¾ mi. NW.	F. Dulier	Upland	1,190	110	5⅝
626	Gans	¼ mi. W.	Mrs. Protzman	Hillside	1,025	90	5⅝
629	Cheat Haven	½ mi. NW.	L. D. Sisler	Valley	810±	75±	5⅝

Chief aquifer			Depth to which well is cased	Water level above (+) or below (—) surface	Method of lift	Capacity of pump	Rate of inflow	Use of water	Remarks
Depth below surface	Character of material	Geologic horizon							
Feet			Feet	Feet		Gallons per minute	Gallons per minute		
100	Sandstone	Connellsville sandstone	60	—50	Manual. force pump	1–3	Ample	Domestic	
110 & 195	Sandstone	Morgantown sandstone	50	—10	None	----------	----------	None	Salt water. Well not developed; salinity from leakage of near by oil wells (?).
20	Sandstone	Saltsburg sandstone	20	+2±	Manual force pump	1–3	5+	Highway camp and lunch	Slight natural flow, hill wash serving as upper confining bed.
Near base	Coarse sandstone	Worthington sandstone	20	—30	Manual, force pump	1–3	Ample	Domestic	Iron-bearing water.
30	Sandstone	Kittanning sandstone±	20	+3	Natural flow	----------	3±	None	Map location approximate. Near Stewarton station, B. & O. R. R.
90	Shale	Basal part of Allegheny formation	20	—50	Manual, force pump	1–3	Ample	Domestic	
60	Limestone	Clarksburg Limestone	20	—50	Manual, force pump	1–3	2	Drinking	
35–50	Limestone	Lower Pittsburgh limestone	12–20	—30±	Manual, force pumps	1–3	5+	Domestic	Three wells.
Near base	Shale	Redstone limestone±	32	—70	Automatic electric, force pump	1	1±	Household	
50	Limestone	Clarksburg limestone	33	—40	Manual, force pump	1–3	½±	Domestic	
Near base	Shale	Bakerstown coal±	35	—40	Automatic electric, force pump	2(?)	Ample	Domestic	

No. on Fig. 37	Location: Nearest P. O.	Location: Distance and direction from P. O.	Owner or name	Topographic situation	Altitude above sea level	Depth of well	Diameter of well
					Feet	Feet	Inches
	Vanderbilt Borough						
585	Vanderbilt	0	Joe Barklow	Terrace	975±	75	$5\frac{5}{8}$
	Washington Township						
566	Fayette City	$1\frac{1}{4}$ mi. N.	John Regal	Terrace	950	80	$5\frac{5}{8}$
567[a]	Fayette City	$1\frac{1}{2}$ mi. SE.	George Bedner	Valley	800±	$33\frac{1}{2}$	$5\frac{5}{8}$
	Fayette City	$\frac{1}{4}$ mi. S.	Peter Jesseck	Valley	800±	65	$5\frac{5}{8}$
	Wharton Township						
630[b]	Chalk Hill	$1\frac{3}{4}$ mi. NW.	Washington Springs	Hillside	2,425	0	----------
631	Chalk Hill	$\frac{3}{4}$ mi. NE.	Mrs. Emma J. Raymond	Hillside	2,010	75	$5\frac{5}{8}$
632[b]	Chalk Hill	$\frac{1}{2}$ mi. SW.	Fayette Springs	Valley	1,875	0	----------
633[a]	Farmington	$1\frac{1}{2}$ mi. NW.	William Burley	Hillside	1,940	80	$5\frac{5}{8}$
634	Farmington	$\frac{1}{2}$ mi. NW.	Ed. Cornish	Hillside	1,900	315	$6\frac{1}{4}$
635[a]	Farmington	2/3-mi. SE.	Gorley's Lake Hotel	Hillside	1,850	393	$5\frac{5}{8}$
636	Farmington	$2\frac{1}{2}$ mi. SE.	John Reisinger	Terrace	2,100	85	$5\frac{5}{8}$
637	Fairchance	$3\frac{1}{2}$ mi. SE.	Rev. Kirby	Ridge crest	2,700±	285	$5\frac{5}{8}$
1103	Gans	$4\frac{3}{4}$ mi. E.	John Gump	Hillside	2,200±	2,100	10–$6\frac{1}{4}$
1104[b]	Gans	$4\frac{3}{4}$ mi. E.	Collins	Valley	2,150±	500	10–$6\frac{1}{4}$

[a] Analysis of water by United States Geological Survey.
[b] Flowing well or spring.

Chief aquifer			Depth to which well is cased	Water level above (+) or below (—) surface	Method of lift	Capacity of pump	Rate of inflow	Use of water	Remarks
Depth below surface	Character of material	Geologic horizon							
Feet			Feet	Feet		Gallons per minute	Gallons per minute		
75±	Base of sandstone	Connellsville sandstone	18	—35	Automatic electric, force pump	----------	3	Domestic	Formerly supplied livery barn.
70	Limestone	Redstone limestone ±	----------	—40	Manual, force pump	1-3	3-5	Domestic	
25	Limestone	Lower Pittsburgh limestone	20±	----------	Manual, force pump	1-3	Ample	Domestic	
50	Shale and limestone	Clarksburg limestone ±	----------	—30	Manual, force pump	1-3	5+	Domestic	Not located on map.
0	Sandstone	Burgoon sandstone	----------	----------	Natural flow	----------	20-50	Domestic	
40	Sandstone	Mahoning sandstone	12	—3	Manual, suction pump	1-3	½±	Domestic	
0	Sandstone	Kittanning sandstone	----------	----------	Natural flow	----------	2±	None	Former resort. Iron-bearing water.
Near base	----------	Mahoning sandstone (?)	15	—30	Manual, force pump	1-3	1½	Domestic, highway garage	Mt. Washington garage.
200	Sandstone	Freeport sandstone	20	—90	Manual, force pump	1-3	25±	Domestic	Specific capacity about 1/3 g. p. m. per foot drawdown.
385	----------	Homewood sandstone (?)	302	—90	Electric, force pump	10	10+	Hotel supply	Maximum consumption about 10,000 gallons a day.
Near base	Sandstone	Freeport sandstone ±	----------	----------	Manual, force pump	1-3	Ample	Domestic	
Near base	Limestone (?)	Greenbrier limestone (?)	20	—245	Manual, force pump	1±	1/3±	Domestic	Map location approximate.
60	Sandstone	Burgoon sandstone	----------	—15±	None	----------	----------	----------	Fresh water; no water found below Burgoon sandstone.
460	Sandstone	Murrysville sand ±	----------	+?	None	----------	----------	None	Fresh water. Located in Wynp's Gap.

Driller's log of David Kinneer well at Acme

(No. 573, Fig. 37.)

	Thickness (Feet)	Depth (Feet)
Soil	3	0-3
Sandstone, friable at base, water at 50 feet	51	3-54
Fireclay, white	3	54-57
Limestone (Vanport), dark, water at base	5	57-62

Driller's log of C. C. Hilderbrand well at Davidson

(No. 597, Fig. 37.)

	Thickness (Feet)	Depth (Feet)
Soil and rock waste	6	0-6
Sandstone, coarse-grained, not water-bearing	60	6-66
Shale, black	80	66-146
Limestone (Colvin Run)	20	146-166
Shale, light gray	15	166-181
Sandstone (Waynesburg) coarse-grained near base	40	181-221

GREENE COUNTY

TOPOGRAPHY AND DRAINAGE

Greene County occupies the extreme southwestern corner of the State of Pennsylvania and lies wholly within the Kanawha section of the Appalachian Plateaus. Monongahela River borders the county on the east and receives the drainage from the greater part of the area through its eastward-flowing tributaries—Dunkard, Whiteley, Little Whiteley, and Tenmile creeks. The western fourth of the county is drained westward into Ohio River by Pennsylvania Fork of Fish Creek and by the two main branches of Wheeling Creek. As in Washington County, the topography differs notably from the dissected peneplain that exists north of the Ohio Valley, the transverse profiles of the ridges being relatively acute and adjacent crests not being accordant in elevation. Although the elevations of adjacent summits differ by 100 feet or more, there is a progressive decrease in the average elevation from 1,500 to 1,600 feet above sea level in the western part of the county—along the divide between the Monongahela and Ohio basins—to 1,300 to 1,500 feet above sea level in the eastern part. The maximum elevation, approximately 1,625 feet above sea level, is attained by an unnamed summit about 2 miles north of Graysville Borough on the drainage divide. A second crest, located some 3 miles east of New Freeport and 3½ miles north of the State boundary line is slightly more than 1,600 feet above sea level. Below the crests, the terrane descends by smooth steep slopes to narrow V-shaped valleys, the local relief being 300 to 500 feet in the western part of the county but usually not more than 400 feet in the eastern part. The extreme relief within the county is 865 feet, the minimum altitude of 760 feet above

sea level being in the Monongahela Valley. The lowest elevation attained by the tributaries of Ohio River along the western boundary of the county and State is approximately 835 feet above sea level.

AREAL GEOLOGY

The Carboniferous rocks which crop out in Greene County range in age from upper Conemaugh to the youngest known in southwestern Pennsylvania. The composite stratigraphic column, which includes full sections of the Monongahela and Washington formations, is approximately 1,775 feet thick. The oldest beds, approximately at the horizon of the Elk Lick coal, are exposed in the extreme southeastern corner of the county where the Monongahela River traverses the flank of the Fayette anticline (See Plate I). The youngest beds, 100 feet above the Windy Gap limestone member of the Greene formation, form the highest hilltop of the Nineveh syncline half a mile northwest of the village of Morford, in western Aleppo Township. The Conemaugh formation crops out only in the Monongahela Valley in Dunkard and Monongahela townships. The overlying Monongahela formation is exposed along the eastern margin of the county in an irregular band from which salients extend westward into the valleys of Whiteley and Tenmile creeks. In the extreme northwestern corner of the county also, narrow tongues of the formation crop out in the two main branches of Wheeling Creek on the western flank of the Washington anticline. The Washington formation occupies the lower portions of the terrane in the eastern half of the county, narrow serrate bands extending westward in the major drainage ways to and beyond Rogersville Borough. Farther west its beds are exposed by Wheeling Creek as that stream crosses the axis and western flank of the Washington anticline. The Greene formation is widespread in the western half of the county, being continuous in the Nineveh syncline and interrupted only by the larger transverse valleys of the Waynesburg syncline. It also caps the ridges of the Whiteley syncline to the east of Waynesburg. These consolidated sediments are overlain successively in the Monongahela Valley by unconsolidated material of two ages, the Carmichaels formation of the Illinoian glacial stage and the alluvium of the present erosion cycle.

GEOLOGIC STRUCTURE

Within Greene County the rocks are deformed by a number of subparallel folds whose axes strike N.25-45°E. and plunge southward 0°-20′ or less. These structural features are shown on an accompanying map (Pl. I) by contours drawn as though on the base of the Pittsburgh coal as an index stratum. Inasmuch as the Carboniferous sediments are essentially conformable, the deformation of any given water-bearing stratum is similar to that of the index bed so that changes in its elevation between a known and a prospective well site may be read directly from the map. In succession from the west these folds are known as Washington anticline, Nineveh syncline, Amity anticline, Waynesburg syncline, Bellevernon anticline, Whiteley syncline, and Brownsville anticline. Each is an open fold with somewhat undulatory flanks dipping 3° or less, the inclination of the beds not exceeding 0°-45′ over extensive areas. All but the most westerly, the

Washington anticline, are symmetrical. The axial plane of the last-named fold is inclined westward, although on account of the gentle dip on either flank, it departs but 0°-35′ from the vertical. The relation of geologic structure to ground water occurrence has been discussed on pages 35-36.

GROUND WATER RESOURCES

General features

Those stratigraphic units which are sources of fresh water in Greene County, together with the pages on which their water-bearing properties are discussed at some length, are entered in the subjoined table. Of these the outstanding source bed is the Waynesburg sand stone at or near the base of the Washington formation. The majority of the others yield limited supplies of ground water from bedding plane conduits where they are not deeply buried but are impermeable beneath continuous cover. Not all of the members tabulated yield fresh supplies throughout the county, however, for any rock is likely to contain saline water where it lies more than 100 feet below the major drainage ways. The rocks below the Birmingham shale yield only brines. In general, drilling to a depth exceeding 300 feet for a supply of fresh water does not promise success. The quality of typical ground waters is shown by the analyses which are tabulated on pages 79-80, also by the discussion which accompanies the descriptions of the several water-bearing members. Artesian conditions are not general within the county, the potential areas of artesian flow being noted on pages 66-67.

Sources of fresh water in Greene County

Formation and member	Pages of this report
Carmichaels formation	12
Greene formation:	
Gilmore sandstone	12
Nineveh sandstone and Nineveh coal	13
Fish Creek sandstone	12
Prosperity limestone	13
Donley limestone and associated beds	13
Washington formation:	
Upper Washington limestone	13
Jollytown limestone and Jollytown coal	13
Middle Washington limestone	13
Lower Washington limestone and associated rocks	13
Colvin Run limestone	14
Waynesburg "A" coal and accompanying beds	14
Waynesburg sandstone	14
Monongahela formation:	
Waynesburg coal	14
Waynesburg limestone	14
Uniontown and Benwood limestones	14
Conemaugh formation:	
Lower Pittsburgh limestone	15
Connellsville sandstone	15
Morgantown sandstone	16
Birmingham shale	16

Brave village supply

The village of Brave (population 199), which is located on Dunkard Creek in the south-central portion of the county, is supplied by a drilled well $5\frac{5}{8}$ inches diameter and 250 feet deep (No. 559, Fig. 38). This well encountered ground water in a sandstone lentil below the Middle Washington limestone at a depth of 200 feet. The well is equipped with an electrically driven deep well force pump. The ultimate yield is reported to be $12\frac{1}{2}$ gallons per minute, so that the specific capacity is small even though it is not known quantitatively. Water is pumped into a 25,000-gallon wooden tank placed immediately below the well site and is distributed thence by gravity mains.

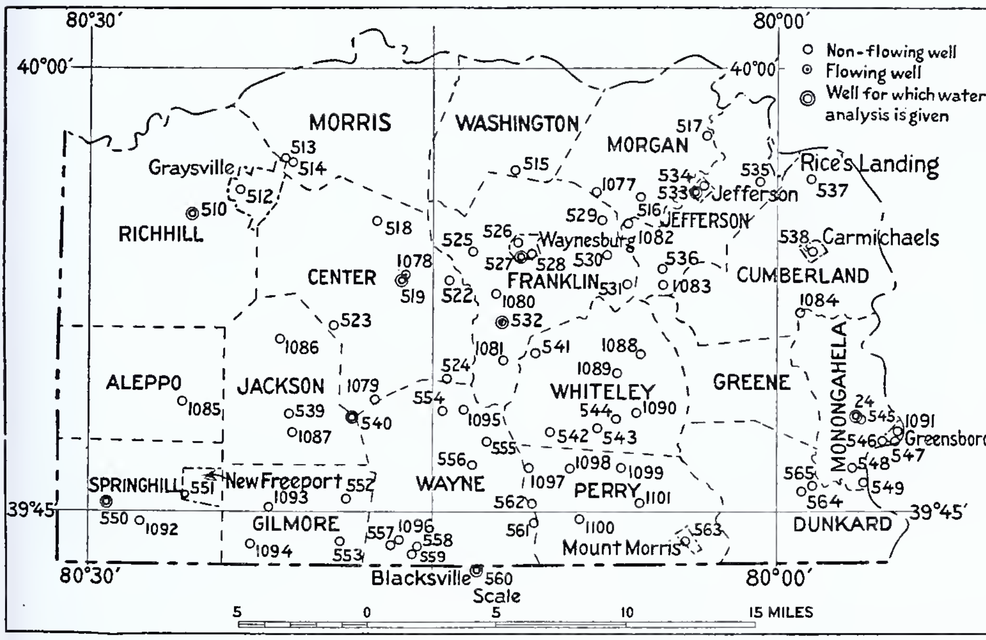


Figure 38. Map of Greene County showing location of wells described in this report.

In the following table of typical wells in Greene County, horizontal rules separate townships and boroughs for ease in reading from the left hand page to the data concerning the same well on the right hand page.

TYPICAL WELLS AND SPRINGS IN GREENE COUNTY, PA.

No. on Fig. 38	Location: Nearest P. O.	Location: Distance and direction from P. O.	Owner or name	Topographic situation	Altitude above sea	Depth of well	Diameter of well
					Feet	Feet	Inches
	Aleppo Township						
1085			Blair A. Michell, No. 4	Hillside	1,150	3,131	8¼-5-3/16
			Armstrong Grim, No. 1		1,205	3,077	------------
			William McQuay, No. 1		1,585	3,428	------------
	Carmichaels Borough						
538	Carmichaels	0	Home Hotel	Terrace	1,000	220	5⅝
	Center Township						
518	Rogersville	2½ mi. N.	Frank Miller	Stream head	1,250±	50	------------
519[a]	Rogersville	0	John Ullom	Hillside	990	38	5⅝
520	Rogersville	0	Lee Buchanan	Terrace	1,025±	60	5⅝
521	Rogersville	0	Jobe Johnson	Hillside	1,000±	135	5⅝
522	Waynesburg	3 mi. SW.	George Basinger	Ridge crest	1,250	122	5⅝
523	Holbrook	½ mi. W.	Harley Huffman	Hillside	1,025	71	5⅝
524	Spraggs	3¼ mi. NW.	Thomas Bros.	Hillside	1,050	109	6¼

[a] Analysis by U. S. Geological Survey.

Chief aquifer: Depth below surface	Chief aquifer: Character of material	Chief aquifer: Geologic horizon	Depth to which well is cased	Water level above (+) or below (—) surface	Method of lift	Capacity of pump	Rate of inflow	Use of water	Remarks
Feet			Feet	Feet		Gallons per minute	Gallons per minute		
1,675	Sandstone	Freeport sandstone	2,784		None			None	Peoples Natural Gas Co. No. 2057 "Top water" cased off at depth 126 feet at Claysville limestone±.
1,758	Sandstone	Kittanning sandstone							
1,950	Sandstone	Homewood sandstone			None			None	
250		Gilmore sandstone±			None			None	
2,315	Sandstone	Clarion sandstone (?)							
		Waynesburg limestone	65	—25	Automatic electric, force pump	3	2±	Domestic	
100	Limestone	Uniontown limestone							
140	Limestone								
		Fish Creek sandstone±			Steam, force pump		3+	Formerly boiler feed	Water supply for standard drilling rig.
31	White sandstone	Jollytown limestone ±	21	—8	Manual, suction pump	1-3	5+	Domestic	
55	**Shale**	Below Upper Washington limestone	10-15	—30	Manual, force pump	1-3	½	Domestic	Not plotted on Fig. 38; near No. 519.
30 and 120	White sandstone	Below Middle Washington limestone	29	—30	Manual, force pump	1-3	1½	Domestic	Not plotted on Fig. 38; near No. 519. Iron-bearing water at depth of 19 feet in red shale cased off.
112	Sandstone	Below Prosperity limestone	15	—30	Manual, force pump	1-3	5+	Domestic	
64	Sandstone	Jollytown limestone ±	43	—12	Manual, force pump	1-3	Ample	Domestic	
45±	Sandstone	Jollytown coal ±	3	—55	Steam, force pump		10+	Abandoned	Former water-supply well at standard rig. Located 1 mile south of village of Oak Forest.

No. on Fig. 38	Location: Nearest P. O.	Location: Distance and direction from P. O.	Owner or name	Topographic situation	Altitude above sea	Depth of well	Diameter of well
					Feet	Feet	Inches
	Center Township—Continued						
1078	Rogersville	0	Mrs Reese	Hillside	1,025±	615	10–6¼
1079	Holbrook	3¾ mi. S.	Agnes Wood	Valley	1,150	3,421	13¾–6⅝
	Cumberland Township						
537	Crucible	0	Pittsburgh Coal Co.	Terrace	1,000	362	8
1084	Carmichaels	2½ mi. S.	D. C. Stevenson	Valley	950	700	-----
			Biddle	-----	935	2,432	-----
	Dunkard Township						
564	Dunkard	1½ mi. NW.	Jones & Loughlin Steel Co.	Upland	1,170	90–125	5⅝
565	Dunkard	½ mi. N.	Miscellaneous	Terrace	850	70	5⅝
			Furman		-----	1,910	-----

Chief aquifer: Depth below surface	Chief aquifer: Character of material	Chief aquifer: Geologic horizon	Depth to which cased well is	Water level above (+) below (—) or surface	Method of lift	Capacity of pump	Rate of inflow	Use of water	Remarks
Feet			Feet	Feet		Gallons per minute	Gallons per minute		
20	Sandstone	Jollytown coal ±	300		None		2±	None	Located near old grist mill.
80	Sandstone	Below Middle Washington limestone					Large		
200	Sandstone	Waynesburg sandstone (?)		+					Flowed slightly by artesian pressure before cased off.
300±	Coal	Waynesburg coal							
500±	Coal	Sewickley coal					1±		
615	Coal	Pittsburgh coal		—200			Large		
1,035	Sandstone	Morgantown sandstone	2,035		None			None	Peoples Natural Gas Co. No. 1846; 1 mile northeast of village of Bluff.
1,665	Sandstone	Kittanning sandstone							
90	Limestone	Uniontown limestone	362		None		Large	None	Cableway into mine.
460		Morgantown sandstone			None			None	Salt water with oil. Located at village of Ceylon.
600		Saltsburg sandstone							Salt water with oil.
520	Sandstone	Morgantown sandstone			None			None	Salt water with oil.
1,050	Sandstone	Freeport sandstone							Salt water.
1,180	Sandstone	Kittanning sandstone							Salt water.
1,240	Sandstone	Homewood sandstone							Fresh water (?)
1,600	Sandstone	Burgoon sandstone							Salt water.
75±	Limestone	Uniontown limestone	20±	—50	Manual, force pumps	1–3	1±	Domestic	Eleven wells at new townsite of Shannopin.
45±	Sandy black shale	Connellsville sandstone	35	—35	Manual, force pumps	1–3	15 maximum	Domestic	Bobtown community.
926		Mahoning sandstone (?)			None			None	
1,085		Freeport sandstone (?)							

No. on Fig. 38	Location: Nearest P. O.	Location: Distance and direction from P. O.	Owner or name	Topographic situation	Altitude above sea	Depth of well	Diameter of well
					Feet	Feet	Inches
	Franklin Township						
525	Waynesburg	2 mi. W.	Arthur Jones	Valley	975	115	5⅝
529	Waynesburg	3⅓ mi. NE.	Mack Coal Co.	Hillside	1,000	120	5⅝
530	Waynesburg	3½ mi. E.	Elijah Waters	Hillside	1,075	60±	5⅝
531	Waynesburg	4⅓ mi. SE.	J. M. Ketchem	Ridge crest	1,390	72	5⅝
532[a] [b]	Waynesburg	2¾ mi. S.	Charles B. Orndoff	Valley	980	50±	6⅝
1080	Waynesburg	2 mi. SW.		Hillside	1,200	3,360	10–6⅝
1081	Spraggs	4 mi. N.		Hillside	1,250	2,701	10–6⅝
			George B. Orndoff				
			Parmelia Thorp, No. 1	----------	1,135	3,175	----------
			Harvey Andrew, No. 1	----------	----------	2,900	----------
	Gilmore Township						
552	Pine Bank	0	William Meehan	Valley	1,005	50	5⅝
553	Brave	2½ mi. W.	John Lantz	Valley	1,025	45	5⅝
1093	Jollytown	2¾ mi. NW.	Belle and A. B. Lantz	Valley	1,100	2,197	13–6⅝
1094	Garrison	2¼ mi. E.	Emma Taylor et al	Stream head	1,275	3,613	13–6⅝
			Jacob Simpson	----------	----------	2,073	----------
	Graysville Borough						
512	Graysville	0	J. M. Seibert	Hillside	1,120	60	5⅝

[a] Analysis by U. S. Geological Survey.
[b] Flowing well or spring.

Chief aquifer			Depth to which well is cased	Water level above (+) or below (—) surface	Method of lift	Capacity of pump	Rate of inflow	Use of water	Remarks
Depth below surface	Character of material	Geologic horizon							
Feet			Feet	Feet		Gallons per minute	Gallons per minute		
75	**Limestone**	Middle Washington limestone	8-10	—40	Manual, force pump	1-3	1/10	Domestic	
60	Limestone	Waynesburg limestone	20	—30	Manual, force pump	1-3	$\frac{1}{8}$	Domestic	
100	Limestone	Uniontown limestone							
Near bottom	Sandstone	Waynesburg sandstone	10	—25±	Manual, force pump	1-3	Ample	Domestic	
	Shale	Below Prosperity limestone	20	—45±	Manual, force pump	1-3	1±	Domestic	
		Waynesburg sandstone (?)		+10±	Natural flow		30±	Drinking	Flowing well; flow controlled by valves.
1,713	Sandstone	Kittanning sandstone			None			None	Poples Natural Gas Co. No. 1817.
330	Coal	Waynesburg "A" coal			None			None	Peoples Natural Gas Co. No. 2041.
570	Coal	Sewickley coal							
660	Coal	Pittsburgh coal							
1,635	Sandstone	Homewood sandstone							
1,980	Sandstone	Burgoon sandstone			None			None	Salt water
2,767	Sandstone	Gordon sand			None			None	
Near base	Sandstone (?)	Upper Washington limestone±	20	—10	Manual, suction pump	1-3	15+	Domestic	
		Jollytown coal ±			Manual, force pump	1-3	Ample	Domestic	
65		Prosperity limestone ±	2,064		Bailer		25+	None	Peoples Natural Gas Co. No. 1979.
1,040	Sandstone	Morgantown sandstone					2		"Hole full of water."
1,780	Sandstone	Homewood sandstone					4		
1,950	Sandstone	Kittanning sandstone (?)	2,378		None			None	Peoples Natural Gas Co. No. 2052.
40		Fish Creek sandstone (?)			None			None	
50	Shale	Below Upper Washington limestone	20	—20	Manual, force pump	1-3	5	Domestic	

No. on Fig. 38	Location: Nearest P. O.	Location: Distance and direction from P. O.	Owner or name	Topographic situation	Altitude above sea	Depth of well	Diameter of well
					Feet	Feet	Inches
	Greensboro Borough						
547	Greensboro	0	C. C. Davis	Valley	810	55	5⅝
1091	Greensboro	0	Mary Reed	Valley	810	1,290	----------
	Jackson Township						
39	Nettle Hill	1¾ mi. NE.	Cumridge	Ridge crest	1,500	120	5⅝
540[a]	Holbrook	3½ mi. S.	Walter Lewis	Ridge crest	1,430	87	5⅝
1086	Holbrook	2½ mi. W.	W. E. Higgins	Stream head	1,350	3,836	13¼–6⅝
1087	Nettle Hill	1¾ mi. E.	Laura E. Stockdale	Valley	1,150	3,371	13¼–6⅝
			Staggers heirs, No. 2	--------------------------	1,190	3,099	----------
	Jefferson Township and Borough						
533[a]	Jefferson	0	L. L. Cree	Terrace	965	36	5⅝
534	Jefferson	0	Winston Smith	Terrace	985	167	5⅝
535	Jefferson	2½ mi. E.	Bunnell	Hillside	970	84	5⅝
536	Fordyce	2¾ mi. N.	Richard Scott	Hillside	1,100	50±	5⅝
1082	Jefferson	2½ mi. SW.	C. G. Manning	Hillside	1,000	2,988	10–6⅝
1083	Fordyce	2 mi. N.	N. B. Johnson	Ridge crest	1,325	3,314	13¼–6⅝

Chief aquifer: Depth below surface	Chief aquifer: Character of material	Chief aquifer: Geologic horizon	Depth to which well is cased	Water level above (+) or below (—) surface	Method of lift	Capacity of pump	Rate of inflow	Use of water	Remarks
Feet			Feet	Feet		Gallons per minute	Gallons per minute		
Near bottom	Shale	Birmingham shale	30	—20	Automatic electric, suction pump	1-3	20+	Domestic	
60	Shale				None			None	
75	Sandstone	Morgantown sandstone							
426	Sandstone	Mahoning sandstone							
488	Sandstone	Freeport sandstone							
90	Sandstone	Gilmore sandstone(?)	22	—90	Manual, force pump	1-3	Very small	Domestic	
80	Sandstone	Nineveh sandstone	20	—60	Manual, force pump	1-3	½	Domestic	Village of Bluff.
1,945	Sandstone	Kittanning sandstone	2,199		None			None	Peoples Natural Gas Co. No. 1665. "Fresh" water.
1,770	Sandstone	Connoquenessing sandstone	2,072		None			None	Peoples Natural Gas Co. No. 2071.
1,901	Sandstone	Homewood sandstone			None		Large	None	"Hole full of water."
35	Sandstone	Waynesburg sandstone	20	—13	Manual, force pump	1-3	3+	Domestic	
100	Limestone	Waynesburg limestone	70	—25±	Automatic electric, force pump		1	Domestic	
140	Limestone	Uniontown limestone							
80	Limestone	Uniontown limestone	45	—15	Manual, force pump	1-3	1½±	Domestic	
Near bottom		Lower Washington limestone(?)			Manual, force pump	1-3	Ample	Domestic	
1,300	Sandstone	Homewood sandstone	1,579		None		Large	None	Peoples Natural Gas Co. No. 1266. "Hole full of water."
1,620	Sandstone	Kittanning sandstone	2,106		None			None	Peoples Natural Gas Co. No. 1756.
1,760	Sandstone	Homewood sandstone							

No. on Fig. 38	Location: Nearest P. O.	Location: Distance and direction from P. O.	Owner or name	Topographic situation	Altitude above sea	Depth of well	Diameter of well
					Feet	Feet	Inches
	Monongahela Township						
24[a]	Mapletown	0	H. J. Williamson	Terrace	1,000	26	30
545	Mapletown	0	Mapletown High School	Terrace	1,000	165±	7⅝
546	Greensboro	⅓ mi. W.	Penn-Pitt School	Hillside	975	120	5⅝
548	Dilliner	2 mi. NW.	Maple-Sterling Coal Co.	Hilltop	1,025	250±	5⅝
549	Dillner	1¼ mi. NW.	Moffitt-Sterling Coal Co.	Valley	825	145±	5⅝
			A. P. Longanecker	----------	----------	1.842	----------
			John Steel	----------	810±	1,344	----------
	Morgan Township						
516	Jefferson	2¼ mi. W.	Mrs. David Thistlethwaite	Hillside	1,090	68	5⅝
517	Jefferson	2¼ mi. N.	Chartiers-Southern Coal Co.	Hilltop	850±	65	6⅝
1077	Waynesburg	3½ mi. NE.	S. A. and Katie Hoge	Hillside	1,150	1,445	10–6⅝
			Eliza Shape, No. 1	----------	----------	3,607	----------

Chief aquifer			Depth to which well is cased	Water level above (+) or below (—) surface	Method of lift	Capacity of pump	Rate of inflow	Use of water	Remarks
Depth below surface	Character of material	Geologic horizon							
Feet			Feet	Feet		Gallons per minute	Gallons per minute		
24	Sand	Carmichaels formation	To bottom	—24	Automatic electric, suction pump	3	Ample	Domestic	Dug well.
30	Limestone	Uniontown limestone	25	—30	Automatic electric, force pump	10	2-3	Drinking	
120	Limestone	Benwood limestone							
90	Shale	Below Lower Pittsburgh limestone	20	—70	Automatic electric, force pump		10+	Drinking	
110	Limestone	Benwood limestone(?)			None			Domestic	Drilled into mine for pump discharge conduit.
	Sandstone	Morgantown sandstone	40	—25	Suction		15+	Abandoned	
985		Kittanning sandstone±			None			None	
1,685	Sandstone	Burgoon sandstone							
485	Sandstone	Butler sandstone			None			None	
515	Sandstone	Freeport sandstone							
551	Black sandy shale	Upper Kittanning coal (?)							
710	Sandstone	Kittanning sandstone							
810	Sandstone	Clarion sandstone					Large		"Hole full of water."
68	Sandstone	Waynesburg sandstone	8	—18	Manual, force pump	1-3	½±	Domestic	
45	Limestone	Benwood limestone	15±	—10	Manual, force pump	1-3	10	Domestic	
810	Sandstone	Morgantown sandstone	1,381		None			None	Peoples Natural Gas Co. No. 2008. Fresh water.
1,709	Sandstone	Pottsville formation			None			None	Salt water.

No. on Fig. 38	Location: Nearest P. O.	Location: Distance and direction from P. O.	Owner or name	Topographic situation	Altitude above sea	Depth of well	Diameter of well
					Feet	Feet	Inches
	Morris Township						
513	Graysville	2 mi. NE.	Frank Rutan	Hillside	1,350	85	5⅝
514	Graysville	2 mi. NE.	Alfred Rutan	Valley	1,200	53	5⅝
			Bristor Bros., No. 1	----------	1,175	2,708	----------
	Mount Morris Borough						
563	Mount Morris	0	Mary Harrison	Terrace	900	65	5⅝
	New Freeport Borough						
551	New Freeport	0	M. L. Hennen	Valley	1,060	48	5⅝
	Perry Township						
562	Spraggs	3 mi. SE.	Earl Wade	Valley	1,020	30	5⅝
1097	Spraggs	2 mi. E.	D. M. Cowell	Hillside	1,275	3,345	10–6⅝
1098	Kirby	2¾ mi. SW.	Eli Fox, No. 1	Valley	1,135	3,333	10–6⅝
1099	Kirby	2 mi. S.	Noah L. and Ocie Haines	Hillside	1,225	2,791	10–6⅝
1100	Mount Morris	4 mi. W.	A. B. Minor, No. 1	Stream head	1,150	3,770	10–6⅝
1101	Mount Morris	2¼ mi. NW.	Owen S. Renner	Stream head	1,125	2,038	10–6⅝

Chief aquifer			Depth to which well is cased	Water level above (+) or below (—) surface	Method of lift	Capacity of pump	Rate of inflow	Use of water	Remarks
Depth below surface	Character of material	Geologic horizon							
Feet			Feet	Feet		Gallons per minute	Gallons per minute		
35	Shale	Below Gilmore sandstone	10	—12±	Manual, force pump	1-3	1	Stock	
40	Shale	Below Nineveh coal	12	—15	Manual, force pump	1-3	1±	Domestic	
1,390	Sandstone	Saltsburg sandstone			None			None	
60	Sandstone	Waynesburg sandstone±	18	—20	Manual, force pump	1-3	Ample	Household	
28	Sandstone	Fish Creek sandstone	12	—10	Manual, suction pump	1-3	3	Household	
21 and 30	Shale (?)	Jollytown limestone±	14	—8±	Manual, force pump	1-3	Ample	Household	
1,717	Sandstone	Homewood sandstone	2,052		None			None	Peoples Natural Gas Co. No. 2021.
1,995	Sandstone	Burgoon sandstone	2,133		None			None	Peoples Natural Gas Co. No. 2051.
790	Coal	Sewickley coal	2,108		None			None	Peoples Natural Gas Co. No. 2074.
890	Coal	Pittsburgh coal							
1,745	Sandstone	Kittanning sandstone							
1,085	Coal	Pittsburgh coal	2,312		None			None	Peoples Natural Gas Co. No. 2004.
1,940	Sandstone	Kittanning sandstone							
2,460	Sandstone	Burgoon sandstone							
90		Upper Washington limestone ±							
1,685	Sandstone	Homewood sandstone	1,905		None			None	Peoples Natural Gas Co. No. 1997.

No. on Fig. 38	Location: Nearest P. O.	Location: Distance and direction from P. O.	Owner or name	Topographic situation	Altitude above sea level	Depth of well	Diameter of well
					Feet	Feet	Inches
	Richhill Township						
510[a]	Wind Ridge	¾ mi. NE.	John Burns	Ridge crest	1,425	77	5⅝
511	Wind Ridge	¾ mi. NE.	John Burns	Hillside	1,375±	55	6
			William Clutter, No. 1	----------	1,080	2,782	----------
			Conkey	----------	1,145	2,600	----------
			Sarah Burroughs No. 1	----------	1,020	3,175	----------
			Harvey Conkey, No. 1	----------	1,350±	2,886	----------
	Springhill Township						
550[a]	Deep Valley	0	George Grimm	Valley	1,020	92	5⅝
1092	Deep Valley	¾ mi. SE.	M. E. Ricthea	Valley	1,075	3,418	10–6⅝
			W. H. Dye, No. 1	----------	1,165	2,992	----------
			D. K. Phillips, No. 1	----------	1,385	3,205	----------
			Jeff Dye, No. 1	----------	1,275±	3,111	----------
			Jacob Rice, No. 12	----------	1,370±	3,194	----------
			S. E. Martin, No. 3	----------	1,365±	2,075	----------
			Russell Sammons, No. 3	----------	1,280	3,184	----------
	Washington Township						
515	Waynesburg	3¼ mi. N.	Challen Lewis	Ridge crest	1,325	80	5⅝

Chief aquifer			Depth to which well is cased	Water level above (+) or below (—) surface	Method of lift	Capacity of pump	Rate of inflow	Use of water	Remarks
Depth below surface	Character of material	Geologic horizon							
Feet			Feet	Feet		Gallons per minute	Gallons per minute		
Near bottom	Shale	Donley limestone ±	10±	—35	Manual, force pump	1-3	½±	Domestic	
38	Sandstone	Above Donley limestone	12	—18	Steam jet		1¼	Abandoned	Water-supply well at standard rig Located near No. 510. "Hole full of water."
260		Waynesburg sandstone (?)			None		Large	None	
1,570 and 1,595		Mahoning sandstone ±			None			None	Salt water.
1,685	Sandstone	Kittanning sandstone			None			None	
1,840	Sandstone	Homewood sandstone							
1,695	Sandstone	Homewood sandstone			None			None	
85	Sandstone	Above Donley limestone	20	—17	Manual, force pump	1-3	5+	Domestic	
1,770	Sandstone	Connoquenessing sandstone			None			None	Peoples Natural Gas Co. No. 2067.
1,343	Sandstone	Saltsburg sandstone			None			None	
1,330	Sandstone	Morgantown sandstone			None			None	
2,050	Sandstone	Homewood sandstone							
3,020	Sandstone	Fifty-foot sand			None			None	
1,896	Sandstone	Freeport sandstone			None			None	
1,110	Coal	Pittsburgh coal			None			None	
1,410	Sandstone	Morgantown sandstone							
1,315	Sandstone	Morgantown sandstone			None		4½±	None	
1,931	Sandstone	Kittanning sandstone							
2,098	Sandstone	Homewood sandstone							
Near bottom	Shale	Below Nineveh coal	10±	—25	Manual, force pump	1-3	1±	Domestic	

No. on Fig. 38	Location: Nearest P. O.	Location: Distance and direction from P. O.	Owner or name	Topographic situation	Altitude above sea level	Depth of well	Diameter of well
					Feet	Feet	Inches
	Wayne Township						
554	Spraggs	$2\frac{1}{4}$ mi. NW.	Kinsley School	Ridge crest	1,520	78	$5\frac{5}{8}$
555	Spraggs	$\frac{3}{4}$ mi. NE.	Spraggs School	Hillside	1,090	49	$5\frac{5}{8}$
556	Spraggs	$\frac{1}{2}$ mi. SW.	Josephus Nichols	Valley	1,030	80	$5\frac{5}{8}$
557	Brave	1 mi. NW.	Mathew Cole	Valley	980	69	$5\frac{5}{8}$
558	Brave	$\frac{1}{4}$ mi. N.	Ulysses Lantz	Hillside	1,150±	312	$5\frac{5}{8}$
559	Brave	$\frac{1}{4}$ mi. W.	William Kant	Hillside	1,125±	250	$5\frac{5}{8}$
560[a]	Blacksville, W. Va.	0	Mack Steele	Valley	990	250	$5\frac{5}{8}$
561	Blacksville, W. Va.	$2\frac{1}{2}$ mi. NE.	------------	Valley	1,000	100	------------
1095	Spraggs	2 mi. N.	Furman E. Orndoff et al	Hillside	1,250	3,405	10–$6\frac{5}{8}$
1096	Brave	1 mi. NW.	H. W. Kent, Agent	Hillside	1,200	3,095	13–$6\frac{5}{8}$
			William Lantz, No. 2	------------	995	2,963	------------
			Thomas Hoy, No. 1	------------	1,030	3,028	------------
			William Lantz, No. 6	------------	------------	2,978	------------
			Kent-Ingraham, No. 5	------------	1,105	3,079	------------
			J. C. Cole, No. 2	------------	1,310	3,280	------------

Chief aquifer: Depth below surface	Chief aquifer: Character of material	Chief aquifer: Geologic horizon	Depth to which well is cased	Water level above (+) or below (—) surface	Method of lift	Capacity of pump	Rate of inflow	Use of water	Remarks
Feet			Feet	Feet		Gallons per minute	Gallons per minute		
70	Sandstone	Nineveh sandstone	25	—20±	Manual, force pump	1-3	5+	Drinking	
45	Sandstone	Jollytown coal ±	32	—20	Manual, force pump	1-3	½	Drinking	
70	Sandstone	Jollytown coal ±	20±	—10	None		4+		Drilled for water supply well at standard rig; pumped with steam suction pump for highway construct.on, 1926.
65	Red shale	Jollytown limestone	20	—50	Manual, force pump	1-3	Ample	Domestic	
30	Sandstone	Below Prosperity limestone			None		See note	None	Drilled for town supply at Brave; yield 10 gallons a day at 30 feet and none below. Base of well about at Lower Washington limestone.
200	Sandstone	Below Middle Washington limestone (?)	20±	—200(?)	Electric, force pump	12½	15±	Municipal supply	
Near bottom	Sandstone	Waynesburg sandstone	20	—25	Manual, force pump	1-3	10+	Domestic	Located in Monongalia County, West Virginia.
	None				None			None	Dry holes, village of Brock. Bottoms of wells reach upper part of Washington formation.
1,815		Homewood sandstone ±	2,138		None			None	Peoples Natural Gas Co. No. 1954.
745	Coal	Sewickley coal	2,089		None			None	Peoples Natural Gas Co. No. 1991.
849	Coal	Pittsburgh coal							
1,714	Sandstone	Homewood sandstone							
2,185	Sandstone	Burgoon sandstone							
1,360	Sandstone	Freeport sandstone			None			None	
1,460	Sandstone	Kittanning sandstone							
2,175	Sandstone	Burgoon sandstone			None			None	
1,520	Sandstone	Homewood sandstone			None		Large	None	"Hole full of water."
2,070	Sandstone	Burgoon sandstone							
2,187	Sandstone	Burgoon sandstone			None		Large	None	"Hole full of water."
60		Fish Creek sandstone (?)			None			None	
1,705	Sandstone	Kittanning sandstone					3±		
1,875	Sandstone	Homewood sandstone							

No. on Fig. 38	Location: Nearest P. O.	Location: Distance and direction from P. O.	Owner or name	Topographic situation	Altitude above sea level	Depth of well	Diameter of well
					Feet	Feet	Inches
	Waynesburg Borough						
526	Waynesburg	Second Av.	Joseph Patton	Hillside	1,075	40±	5⅝
527[a]	Waynesburg	0	Waynesburg Ice Co.	Valley	980	118	8
528	Waynesburg	0	Greene County Produce Co.	Terrace	990	186	8
	Whiteley Township						
541	Waynesburg	4 mi. S.	Stone School	Valley	1,130	72	5⅝
542	Kirby	2½ mi. SW.	Stevens School	Valley	1,085	65	5⅝
543	Kirby	¾ mi. SW.	Cole & Knight	Valley	1,100±	60	5⅝
544[b]	Kirby	0	Kirby School	Valley	1,010	53	5⅝
1088	Kirby	2¾ mi. NE.	Smith Fuller et ux	Ridge crest	1,325	2,085	10–6⅝
1089	Kirby	1¾ mi. N.	B. R. Stevens et al	Valley	1,075	3,300	10–6⅝
1090	Kirby	1 mi. NE.	Harry Stevens	Valley	1,025	3,258	10–6⅝

[a] Analysis of water by United States Geological Survey.
[b] Flowing well or spring.

Chief aquifer: Depth below surface	Chief aquifer: Character of material	Chief aquifer: Geologic horizon	Depth to which well is cased	Water level above (+) or below (—) surface	Method of lift	Capacity of pump	Rate of inflow	Use of water	Remarks
Feet			Feet	Feet		Gallons per minute	Gallons per minute		
Near bottom 115	Dark shale	Above Lower Washington limestone	15	-8 to 10	Manual, force pump	1-3	2±	Formerly domestic	Near by wells yield 1 to 10 gallons a minute.
		Waynesburg sandstone (?)	----	—18	Electric, force pump	40	65+	Condensers	Wells at flour mill and electric light plants ½ mile away from No. 527, failed to find water; depth 200 feet.
35 80	Limestone ----	Colvin Run limestone Waynesburg sandstone	9	—12±	----	----	35+	Condensers	----
60	Shale	Above Lower Washington limestone	30	—20	Manual, force pump	1-3	10+	Drinking	----
55	Shale	Above Lower Washington limestone	18	—20	Manual, force pump	1-3	10	Drinking	----
Near bottom	Limestone	Upper Washington limestone	6-8	—3	Steam, suction pump	----	5+	Abandoned	Water supply well for 3 standard rigs. Map location doubtful.
Near bottom	Shale	Waynesburg sandstone (?)	8-10	—15	Manual, force pump	1-3	Ample	Drinking	----
245	----	Above Lower Washington limestone (?)	2,032	----	None	----	----	None	Peoples Natural Gas Co. No. 1993.
1,600 1,660	Sandstone Sandstone	Kittanning sandstone Clarion sandstone	---- ----	---- ----	---- ----	---- ----	---- ----	---- ----	---- ----
1,539	Sandstone	Homewood sandstone	2,074	----	None	----	----	None	Peoples Natural Gas Co. No. 2001.
1,525	Sandstone	Homewood sandstone	1,849	----	None	----	----	None	Peoples Natural Gas Co. No. 2062. "Top water" shut off made in Lower Pittsburgh limestone, depth 678 feet.

WASHINGTON COUNTY

TOPOGRAPHY AND DRAINAGE

Washington County (See Pl. I), lies between the widespread limbs of a U-shaped drainage way which comprises Monongahela River on the east and Ohio River on the north and west. The western limb of this drainage way lies in West Virginia, between 4 and 12 miles from the western boundary of Pennsylvania. From a center slightly south of the city of Washington the terrane enclosed by these major streams is drained radially, eastward by Tenmile Creek and other tributaries of Monongahela River, northward to Ohio River by Raccoon and Chartiers creeks, and westward by Harmon, Cross, and Buffalo creeks as well as by Enlow Fork of Wheeling Creek. These streams and their interfingering secondary tributaries form a dendritic drainage pattern of very fine texture. The topography of the county differs notably from the typical dissected peneplain of Butler County, the transverse profiles of the ridges being more acute and the crests much shorter. Moreover, adjacent summits are not accordant in elevation but differ by as much as 150 feet, although there is a progressive increase in the average elevation from 1,200 to 1,375 feet above sea level in the north to 1,300 to 1,500 feet above sea level in the south. The maximum elevation, slightly more than 1,500 feet, is attained by Sampson Hill and by Mosier Hill in the vicinity of Claysville Borough. Below these crests the terrane descends by smooth but relatively steep slopes to narrow valleys, the local relief ranging from 300 to 500 feet. The extreme relief within the county is somewhat greater, or 785 feet.

AREAL GEOLOGY

The sedimentary rocks which crop out in Washington County (See Pl. I) range in age from middle Conemaugh on the north to middle Greene on the south, the composite stratigraphic column, which includes full sections of the Monongahela and Washington formations, being approximately 1,450 feet thick. The oldest beds, approximately at the horizon of the Bakerstown coal, are exposed in the Kings Creek Valley on the western flank of the West Middletown syncline (Pl. I); the youngest, the shaly strata above the Nineveh sandstone member of the Greene formation, crop on the hilltops of the Nineveh syncline at the boundary between Washington and Greene counties. The principal area of Conemaugh sediments lies in the extreme northwestern corner of the county, north of Harmon and Raccoon creeks. The formation also crops out farther south in the Cross Creek valley and on the crest of the Westland dome near Canonsburg. Along the eastern edge of the county it crops in the Monongahela Valley on the crests of the Bellevernon and Amity anticlines. The Monongahela formation forms an irregular serrate band along the northern and eastern borders of the county and covers isolated areas on the Westland dome, on the flanks of the West Middletown syncline in Buffalo Creek valley, and on the crest of the Amity anticline at the village of Lone Pine. The Washington formation occupies a most irregular band which outlines the southwest quadrant of the county and from which broad tongues extend northward in the West Middletown and Nineveh synclines to the latitude of Midway Borough. It also caps the ridge crests

of the Cross Creek syncline in the north-central part of the county, and is exposed by the heads of Enlow Fork in the southwestern corner. The youngest beds, the Greene formation, occupy the higher part of the terrane in the West Middletown and Nineveh synclines on the southwestern quadrant and form isolated hilltop caps as far north as the village of Cross Creek. They also form isolated exposures in the Waynesburg syncline farther east.

GEOLOGIC STRUCTURE

The Carboniferous sediments of Washington County are deformed by a number of symmetrical sub-parallel folds whose axes, in the greater part of the area, strike N.30-45°E. and plunge gently southward. In sequence from the west, those which have been given geographic names are the West Middletown, Finney, Nineveh, and Waynesburg (Pigeon Creek) synclines and the alternating folds—the Claysville, Washington, Amity, and Bellevernon anticlines. These structural features are shown on an accompanying map (Pl. I) by contours drawn as though on the base of the Pittsburgh coal at the bottom of the Monongahela formation. In general the folds of Washington County are broader and more definite than those of the districts farther north, although in terms of absolute magnitude they are rather gentle plications. Usually the dip of the beds is less than 2° and does not exceed 0° 30′ over extensive areas. The slope of the axes rarely exceeds half a degree. Inasmuch as the Carboniferous sediments are essentially conformable throughout, the flexures of any stratum are similar to those of the index bed, the Pittsburgh coal, and may be determined approximately from the map by inspection. The general relations between geologic structure and mode of occurrence of ground water has been discussed on pages 35-36.

In the northwestern quadrant of the county the axes of the West Middletown and Nineveh synclines swerve sharply and strike N.5-10°E. Between them lies a relatively close transverse fold, the Cross Creek syncline, and, to the south, the Westland dome, an outstanding quaquaversal flexure against which the Claysville and Washington anticlines and the Finney syncline impinge. This structural condition has an important bearing upon the ground water resources of the district, in that it inhibits ground water circulation from the north and the flushing out of the saline waters trapped in the sediments at the time of deposition.

GROUND WATER RESOURCES

General features

The following table cites those stratigraphic units which are sources of ground water supplies in Washington County, together with the pages on which the water-bearing properties of each are discussed at some length. Of these the outstanding two are the Waynesburg sandstone at the base of the Washington formation, and the Uniontown and Benwood limestones of the underlying Monongahela formation. Locally the sandstone members of the Conemaugh are important source beds, although they lie below the practicable limit of drilling over the greater

part of the county. The quality of the ground waters is shown by the analyses tabulated on pages 75-77, and is discussed in the descriptions of the several water-bearing members to which reference is made below. Artesian conditions are not general within the county, the potential areas of artesian flow being noted on page 68. It is not likely that fresh waters will be found more than 100 feet below the major drainage ways.

Sources of fresh water in Washington County

Formation and member	Pages of this report
Alluvium	111
Greene formation:	
Fish Creek sandstone	130
Donley limestone and associated beds	132
Washington formation:	
Upper Washington limestone	135
Jollytown limestone and associated beds	136
Middle Washington limestone	138
Lower Washington limestone	138
Washington coal	139
Washington sandstone	140
Colvin Run limestone	140
Waynesburg "A" coal	141
Waynesburg sandstone	141
Cassville shale	144
Monongahela formation:	
Waynesburg coal	146
Waynesburg limestone	146
Uniontown sandstone	147
Uniontown and Benwood limestones	148
Sewickley sandstone	151
Fishpot limestone	152
Redstone limestone	153
Pittsburgh sandstone	154
Conemaugh formation:	
Pittsburgh limestones and associated beds	157
Connellsville sandstone	159
Clarksburg limestone	160
Morgantown sandstone	163
Saltsburg sandstone	170

Municipal supplies

Claysville. The water supply of the village of Claysville (population 912), in the west-central part of the county, is derived in part from three wells (No. 367, Fig. 39) drilled in the valley of the head of Dutch Fork of Buffalo Creek. These are 82, 140, and 200 feet deep. The water-bearing horizons which presumably are reached are respectively, the shaly strata which lie above the Lower Washington limestone, the Washington sandstone, and the Waynesburg sandstone. The lithology and water-bearing properties of the strata actually penetrated, however, are unknown. Each of the wells is equipped with a deep well force pump driven by a gas engine. During the summer of 1926 a dam to impound surface water was in process of construction just north of the borough, so that the ground water supply will in the future serve as a standby only.

McDonald. Although the West Penn Water Company, which supplies the communities of McDonald (population 3,281) and Burgettstown (population 1,990), as well as portions of the six adjacent townships, obtains the greater part of its supply by impounding the flow from one of the forks of Raccoon Creek, three drilled wells serve as

an auxiliary supply. These wells (No. 330, Fig. 39), which are on the east bank of Raccoon Creek in the northwestern part of the county, are 10 inches in diameter and between 90 and 100 feet deep, and reach an extremely porous pebbly facies of the Saltsburg sandstone. Two of the wells are equipped with steam-driven Downie double-acting deep well force pumps; the third well is not equipped and is not used. The two wells are pumped as much as three or four months during the dry season, the reported aggregate rate of yield being from 200 to 240 gallons per minute. The specific capacities are not known but are relatively large for a consolidated sandstone. The deep well pumps discharge directly into a 105,000-gallon steel receiving tank at the well site, which has an altitude of 910 feet above sea level. Thence the water is pumped through a 10-inch force main to a 600,000-gallon standpipe on a hilltop north of McDonald Borough at an elevation of 1,200 feet above sea level. Distribution is by gravity mains. Of the total daily consumption, which in 1915 averaged 501,000 gallons, approximately half is for domestic purposes and half for mines of the Pittsburgh Coal Company and the Carnegie Coal Company.

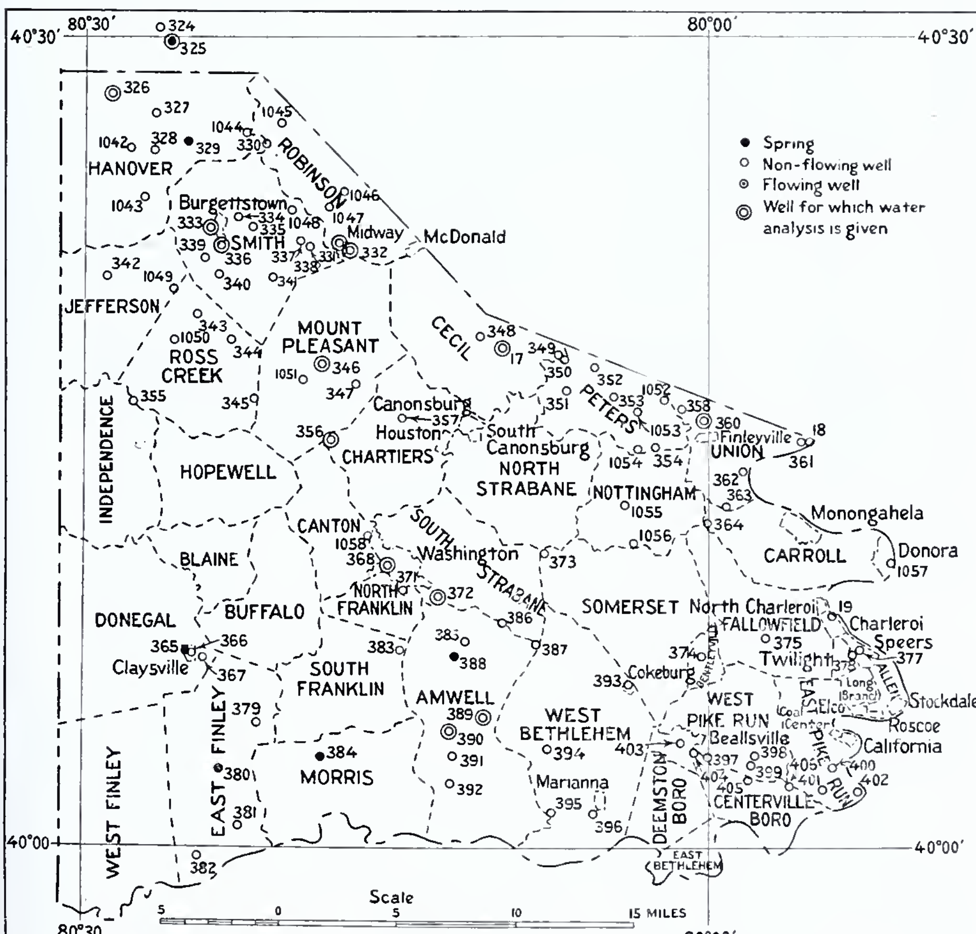


Figure 39. Map of Washington County showing the location of wells and springs described in this report.

TYPICAL WELLS AND SPRINGS IN WASHINGTON COUNTY, PA.

No. on Fig. 39	Location: Nearest P. O.	Location: Distance and direction from P. O.	Owner or name	Topographic situation	Altitude above sea level	Depth of well	Diameter of well
					Feet	Feet	Inches
	Allen Township						
			John B. Carson No. 1	--------	1,035	2,060	--------
	Amwell Township						
385	Washington	$3\frac{1}{2}$ mi. SE.	Red Schoolhouse	Valley --------	1,080	75	$5\frac{5}{8}$
			Tanneyhill	Valley --------	1,175	32	$5\frac{5}{8}$
386	Washington	5 mi. SE					
387	Washington	$6\frac{1}{2}$ mi. SE.	Wm. Hootman	Valley --------	1,085	182	8–6
388[b]	Washington	$4\frac{1}{2}$ mi. SE.	--------	Hillside --------	1,075	0	--------
389[a]	Amity	3 mi. NE.	Carnegie Natural Gas Co.	Valley --------	1,080	85 and 90	$5\frac{5}{8}$
390[a]	Amity	$2\frac{1}{4}$ mi. N.	Ralph H. Keeny	Ridge crest --------	1,330	64	$5\frac{5}{8}$
391	Amity	$1\frac{1}{4}$ mi. N.	Neal Wiley, deceased	Hillside --------	1,225	40	$5\frac{5}{8}$
392	Amity	0	Miscellaneous	Ridge crest --------	1,200	80–90	$5\frac{5}{8}$
			Daniel Baker, No. 1	--------	1,135	3,107	--------
	Beallsville Borough						
403	Beallsville	0	W. B. Hill	Hillside --------	1,160	70	8

[a] Analysis by U. S. Geological Survey.
[b] Flowing well or spring.

Chief aquifer: Depth below surface	Chief aquifer: Character of material	Chief aquifer: Geologic horizon	Depth to which well is cased	Water level above (+) or below (—) surface	Method of lift	Capacity of pump	Rate of inflow	Use of water	Remarks
Feet			Feet	Feet		Gallons per minute	Gallons per minute		
600	Shale (?)	Mahoning sandstone ±	---	---	None	---	---	None	Salt water. Cased off.
900	---	Kittanning sandstone ±	---	---	---	---	---	---	Salt water.
70	Limestone	Middle Washington limestone	46	-9	Manual, force pump	1–3	Ample	Drinking	---
Near bottom	Black shale	Jollytown coal ±	---	---	Manual, force pump	1–3	Ample	Service station	South Strabane community.
28	---	Waynesburg sandstone							
100	Sandstone	Uniontown sandstone ±							
172 (?)	Sandstone	Sewickley sandstone	16	-13	Air lift	30	30±	Swimming pool	Glyde Beach resort. Specific capacity about 0.4 g. p. m. per foot of drawdown.
0	Sandy shale	Above Jollytown limestone	0	---	Natural flow	---	3	Drinking	Spring at roadside.
65	Limestone	Uniontown limestone	20±	—7	Steam, suction pumps	20–50	20–23	Condensers	Lone Pine compressing station. Three wells.
50±	Sandstone	Above Donley limestone	---	—50	Manual, force pump	1–2	Ample	Domestic	---
Near bottom	Sandy shale	Jollytown coal ±	---	---	Manual, force pump	1–2	Ample	Domestic	---
Near bottom	Limestone	Upper Washington or Jollytown limestone	---	---	Manual, force pumps	1–3	Ample	Domestic	Amity community.
1,486	Sandstone	Homewood sandstone	---	---	None	---	2½	None	Salt water, cased off.
1,531	Sandstone	Homewood sandstone	---	---	---	---	Large	None	---
55	Coarse sandstone	Waynesburg sandstone	22	—5	Electric, suction pump	---	10±	Private garage	---

No. on Fig. 39	Location		Owner or name	Topographic situation	Altitude above sea level	Depth of well	Diameter of well
	Nearest P. O.	Distance and direction from P. O.					
					Feet	Feet	Inches
	Bentleyville Township						
374	Bentleyville	1 mi. NE.	Herbert Hertzog	Hillside	1,025	105	$6\frac{5}{8}$
	Blaine Township						
			James McMannis No. 1			2,500	
			Mrs. McClag No.1			2,816	
	Buffalo Township						
			Sprowl and Marshall No. 1		1,130	3,037	
			F. J. Mounts No. 2		1,200	2,809	
			Martha Mounts No. 1		1,290	2,857	
			Wm. Horn No. 3		1,150	2,783	
			A. Kelly No. 4			2,865	

Chief aquifer			Depth to which well is cased	Water level above (+) or below (—) surface	Method of lift	Capacity of pump	Rate of inflow	Use of water	Remarks
Depth below surface	Character of material	Geologic horizon							
Feet			Feet	Feet		Gallons per minute	Gallons per minute		
90	Limestone	Benwood limestone	56	—85	Automatic electric, force pump	3⅔	Ample	Domestic	
1,120	Sandstone	Freeport sandstone			None			None	Salt water, cased off.
1,585	Sandstone	Burgoon sandstone							
2,673	Sandstone	Gordon Stray sand			None		25±	None	Salt water, cased off.
1,550	Sandstone	Worthington sandstone			None			None	Water-bearing members cased off.
1,695	Sandstone	Homewood sandstone					Large		
2,879	Sandstone	Gordon sand					Large		
2,660	Sandstone	Gordon sand			None		1±	None	
2,721	Sandstone	Fourth and Fifth sands					See notes		Inflow about 125 gallons in 5 days.
120	Limestone	Middle Washington limestone			None		Little	None	Water-bearing members cased off.
200		Washington coal(?)					3±		
350		Waynesburg sandstone(?)							
1,560		Homewood sandstone					Large		
1,785	Limestone	Greenbrier limestone							
2,040		Squaw sand(?)					Little		
1,020	Sandstone	Saltsburg sandstone			None		5±	None	Water-bearing members cased off.
1,515	Sandstone	Homewood sandstone					Large		
2,772	Sandstone	Fifth sand							
1,835	Sandstone	Burgoon sandstone			None		1±	None	Cased off.

No. on Fig. 39	Location: Nearest P. O.	Location: Distance and direction from P. O.	Owner or name	Topographic situation	Altitude above sea level	Depth of well	Diameter of well
					Feet	Feet	Inches
	Canton Township						
1058	Washington	$1\frac{3}{4}$ mi. NW.	J. H. Wallace No. 1	----------	----------	2,563	----------
	Washington	$1\frac{1}{2}$ mi. W.	Vandergrift No. 1	----------	----------	2,420	----------
			E. D. Prigg, No. 1	----------	----------	2,873	----------
	Carroll Township						
364	Monogahela	$3\frac{3}{4}$ mi. W.	Nottingham Township School	Upland	1,225	134	$5\frac{5}{8}$
	Cecil Township						
17[a]	Hendersonville	2 mi. NW.	Sam Deblasoi	Valley	1,050	28	$5\frac{5}{8}$
348	Cecil	1 mi. S.	Logan McConnell	Gulch head	1.225	92	$5\frac{5}{8}$
349	Lawrence	0	Sam Ofsay	Terrace	1,020	80	$5\frac{5}{8}$
350	Lawrence	$\frac{1}{4}$ mi. SE.	A. F. Simpson	Valley	860	85	$5\frac{5}{8}$
			Scott	----------	1,055	2,247	----------
			Walker No. 3	----------	----------	2,305(?)	----------
			Charles Carter No. 1	----------	1,085±	----------	----------
			John Burnside No. 4	----------	----------	2,361	----------
			J. C. Stonescraper No. 1	----------	1,185	2,335	----------

Chief aquifer			Depth to which well is cased	Water level above (+) or below (—) surface	Method of lift	Capacity of pump	Rate of inflow	Use of water	Remarks
Depth below surface	Character of material	Geologic horizon							
Feet			Feet	Feet		Gallons per minute	Gallons per minute		
320	Coal	Pittsburgh coal			None		Little	None	Located at Tylerdale. Water-bearing members cased off.
750±	Sandstone	Saltsburg sandstone(?)					Little		Salt water.
1,450±	Sandstone	Burgoon sandstone(?)							Salt water. Cased off.
1,335	Friable sandstone	Homewood sandstone			None		4±	None	
1,360	Hard sandstone	Homewood sandstone(?)					10±		Salt water. Cased off.
2,420	Sandstone	Gordon sand							Salt water.
1,640		Homewood sandstone(?)			None			None	Salt water.
2,500		Murrysville sand(?)							Salt water.
2,725	Sandstone	Boulder sand(?)							Salt water.
Near bottom	Limestone	Waynesburg limestone			Manual, force pump	1–3	Ample	Drinking	
5	Sand	Alluvium	28	Creek level±	Manual, force pump	1–3	Ample	Domestic	
32 40 55		Waynesburg sandstone(?)			Manual, force pump	1–3	1	Domestic	
Near bottom	Shale	Uniontown limestone		—30	Manual, force pump	1–3	½	Drinking	Other wells of community yield up to 10 gallons per minute.
75	Red shale	Below Fishpot limestone			Manual, force pump	1–3	Ample	Domestic	
810	Sandstone	Kittanning sandstone			None		"Much"	None	Located 1 mile northwest of Venice community. Salt water.
2,211	Sandstone	Gordon sand							Salt water.
745		Mahoning or Freeport sandstone			None			None	
1,180	Sandstone	Homewood sandstone		—150	None			None	Drilled in 1909; decline of static level probable.
725	Coal	Upper Freeport coal			None		Little	None	Water-bearing members cased off.
830	Coal	Upper Kittanning coal					Little		
1,130	Sandstone	Homewood sandstone					7±		
		Clarksburg limestone	193		None			None	"Top" water cased off.

No. on Fig. 39	Location: Nearest P. O.	Location: Distance and direction from P. O.	Owner or name	Topographic situation	Altitude above sea level	Depth of well	Diameter of well
					Feet	Feet	Inches
	Centerville Borough						
404	Bealisville	$\frac{2}{3}$ mi. SE.	Nemacolin Country Club	Hilltop	1,280	95	$5\frac{5}{8}$
405	Daisytown	1 mile S.	Grimes and Bakewell	Upland	1,200	100	$5\frac{5}{8}$
406	West Brownsville	$2\frac{3}{4}$ mi. NW.	Charles Butler	Upland	1,180	100	$5\frac{5}{8}$
	Charleroi Borough						
19	Charleroi	0	McBeth-Evans Glass Co.	Stream plain	765	60±	----------
	Chartiers Township						
356[a]	Hickory	$3\frac{1}{2}$ mi. S.	Gretna Oil & Gas Co.	Hilltop	1,250	107	$5\frac{5}{8}$
357	Houston	2 mi. NW.	McCloy & Campbell	Valley	1,015	123	8
			Caltergahn No. 1	----------	----------	2,204	----------
	Claysville Borough						
365[b]	Claysville	0	Claysville Borough	Hillside	1,200±	0	----------
366	Claysville	0	Miscellaneous	Hillside	1,125–1,200	45–75	$5\frac{5}{8}$
	Cokeburg Borough						
393	Cokeburg	0	Bethlehem Mines Corp.	Hillside	1,095	175	$5\frac{5}{8}$ to $4\frac{1}{4}$

Chief aquifer			Depth to which well is cased	Water level above (+) or below (—) surface	Method of lift	Capacity of pump	Rate of inflow	Use of water	Remarks
Depth below surface	Character of material	Geologic horizon							
Feet			Feet	Feet		Gallons per minute	Gallons per minute		
80	Limestone	Colvin Run limestone	26	-80	Manual, force pumps	1-3	Ample	Drinking	
80	Limestone	Uniontown limestone	24	-80	Manual, force pump	1-3	Large	Domestic	Centerville community.
85	Limestone	Waynesburg limestone	28	-85	Manual, force pump	1-3	Large	Domestic	
Near bottom	Sand and gravel	Alluvium			None		Variable	None	Group of 8 test wells, yield varied from "small" to "large." No permanent development.
45	Black shale	Waynesburg coal	20±	-45	Gas engine, force pump	3	3+	Cooling compressing engines	
30	Limestone	Clarksburg limestone	14	-30	Gas engine, force pump	2	6½±	Cooling compressing engines	
858	White sandy shale	Worthington sandstone ±			None			None	Water-bearing members cased off.
998	Gray sandstone	Homewood sandstone							Salt water.
0	Limestone	Jollytown limestone			Natural flow		3±	None	Spring. Abandoned as municipal supply because of contamination.
Near bottom	Limestone and sandy shale	Middle Washington limestone ±	20±		Manual, force pumps	1-3	Ample	Domestic	
145	Coal	Waynesburg coal	80	-145	Manual, force pump	1-3	Ample	Domestic	No. 9 house, row B. Supplies 10-12 families.

No. on Fig. 39	Location: Nearest P. O.	Location: Distance and direction from P. O.	Owner or name	Topographic situation	Altitude above sea level	Depth of well	Diameter of well
					Feet	Feet	Inches
	Cross Creek Township						
343	Cross Creek	0	Miscellaneous	Upland	1,350	50	5⅝
344	Cross Creek	2 mi. SE.	Kelly Bros. & Cooper	Hillside	1,185	157	5⅝
345	Hickory	3¼ mi. SW.	Henry Shaffer	Hilltop	1,345	98	5⅝
1050	Cross Creek	1¼ mi. SW.	G. C. Dunbar No. 1	Upland	1,275	2,159	13–6¼
			Abraham Pry, No. 1	----------	1,260	2,190	----------
			S. C. Cunningham	----------	1,025	2,353	----------
	Deemston Borough						
			Matilda Davis, No. 2	----------	840±	2,120	----------
			J. L. Thompson, No. 1	----------	1,175±	3,056	----------

Chief aquifer			Depth to which well is cased	Water level above (+) or below (—) surface	Method of lift	Capacity of pump	Rate of inflow	Use of water	Remarks
Depth below surface	Character of material	Geologic horizon							
Feet			Feet	Feet		Gallons per minute	Gallons per minute		
15-40	Limestone	Lower Washington limestone	20±		Manual, force pumps	1-3	Ample	Domestic	
Near bottom		Uniontown limestone ±			Manual, force pump	1-3	Ample	Domestic	
90	Top of coal	Waynesburg "A" coal (?)		-90	Manual, force pump	1-3	1-	Domestic	
50		Waynesburg sandstone (?)			None			None	Peoples Natural Gas Co., No. 743. Fresh water, cased off.
1,200	Sandstone	Homewood sandstone							Salt water.
60	Coal	Washington coal							
1,400	Sandstone	Burgoon sandstone			None		Large	None	"Hole full of water."
200	Base of sandstone	Connellsville sandstone			None			None	Cased off.
30±	Limestone	Benwood limestone			None			None	Water-bearing members cased off.
814	Coal	Upper Freeport coal							
993	Sandstone	Freeport sandstone							
80		Washington coal ±			None			None	
1,220	Sandstone	Freeport sandstone							Water-bearing members cased off.
1,300	Sandstone	Worthington sandstone					Large		"Hole full of water" at 1,370 feet.

No. on Fig. 39	Location: Nearest P. O.	Location: Distance and direction from P. O.	Owner or name	Topographic situation	Altitude above sea level	Depth of well	Diameter of well
					Feet	Feet	Inches
	Donegal Township						
367	Claysville	¾-mile SE.	Claysville Borough	Valley	1,150±	82 140 200	6± 6± 6±
			West Alexander	----------	----------	----------	----------
			Samuel Shaler, No. 1	----------	1,050±	2,643	----------
			T. C. Snodgrass, No. 1	----------	----------	2,613	----------
	Donora Borough						
1057	Donora	0	American Steel & Wire Co., No. 3	Valley	765±	1,852	----------
	East Finley Township						
379	Claysville	4 mi. SE.	Pleasant Grove School	Ridge crest	1,400	148	5⅝
380b	Claysville	5 mi. S.	----------	Hillside	1,225	60	5⅝
381	Graysville	5½ mi. N.	Marshall School	Valley	1,225	40–60	5⅝
382	Graysville	4½ mi. N.	Newland School	Hillside	1,390	75	5⅝

Chief aquifer: Depth below surface	Chief aquifer: Character of material	Chief aquifer: Geologic horizon	Depth to which well is cased	Water level above (+) or below (—) surface	Method of lift	Capacity of pump	Rate of inflow	Use of water	Remarks
Feet			Feet	Feet		Gallons per minute	Gallons per minute		
Near bottom		Lower Washington limestone ±			Gas engine, force pumps			Municipal supply	Three wells.
Near bottom		Washington sandstone ±							
Near bottom		Waynesburg sandstone ±							
977	Gray sandstone	Freeport sandstone			None			None	Located on McGraw Run, 3 miles west of West Alexander. Salt water.
1,264	Sandstone	Kittanning sandstone							
1,637	Sandstone	Homewood sandstone							Salt water.
1,255	Sandstone	Homewood sandstone			None			None	Salt water, cased off.
1,311	Sandstone	Connoquenessing sandstone							
1,565	Sandstone	Burgoon sandstone							Salt water.
1,484	Sandstone	Homewood sandstone			None			None	
1,613	Limestone	Loyalhanna limestone					Large		"Wet hole" from 1,613 to 1,780 feet.
855		Pottsville formation			None			None	Salt water, cased off.
119	Limestone	Upper Washington limestone (?)	20±	-119	Manual, force pump	1-3	Ample	Drinking	
0	Micaceous sandstone	Above Donley limestone			Natural flow		5	Roadside trough	Spring.
20	Limestone	Donley limestone ±			Manual, force pump	1-3	Ample	Drinking	
60	Sandstone	Fish Creek sandstone ±			Manual, force pump	1-3	Ample	Drinking	

No. on Fig. 39	Location: Nearest P. O.	Location: Distance and direction from P. O.	Owner or name	Topographic situation	Altitude above sea level	Depth of well	Diameter of well
					Feet	Feet	Inches
	East Pike Run Township						
400	California	1½ mi. SW.	Thomas Elliot	Hilltop	1,125	114	5⅝
401	West Brownsville	1¼ mi. NW.	A. J. Nixon	Hillside	1,150	69	5-5/8
402	West Brownsville	¾ mi. NE.	Forsythe Coal Co.	Valley	800	122–151	8
	Fallowfield Township						
375	Charleroi	3 mi. W.	Harrison Haynan	Ridge crest	1,225	70	5⅝
376	Charleroi	3 mi. W.	J. S. Cole	Ridge crest	1,200±	40	5⅝
	Hanover Township						
324	Florence	5 mi. N.	C. H. Dossett	Hillside	1,125	114	5⅝
325[a, b]	Florence	4½ mi. N.	Frankfort Springs	Valley	1,030	0	------
326[a]	Florence	3¼ mi. NW.	Manufacturers Light & Heat Co.	Valley	1,000	100±	8
327	Florence	1½ mi. N.	E. O. Fullerton	Summit	1,190	60	5⅝
328	Florence	½ mi. W.	James Bell	Upland	1,300±	95±	5⅝
329[b]	Florence	1¼ mi. E.	------	Hillside	1,210	0	------
1042	Florence	1½ mi. W.	James F. Steele	Valley	1,000	1,287	10-6⅝
1043	Florence	2½ mi. SW.	R. A. Thompson	Hillside	1,150	1,790	10-6¼
1044	Florence	3½ mi. E.	McConnell heirs	Hillside	1,000±	1,000±	------

Chief aquifer			Depth to which well is cased	Water level above (+) or below (—) surface	Method of lift	Capacity of pump	Rate of inflow	Use of water	Remarks
Depth below surface	Character of material	Geologic horizon							
Feet			Feet	Feet		Gallons per minute	Gallons per minute		
95	Black shale	Waynesburg coal	45	-95	Manual, force pump	1-3	Ample	Domestic, stock	Small dairy farm.
55	Top of limestone	Colvin Run limestone	30	-55	Manual, force pump	1-3	Ample	Domestic, stock	------
Near bottom	Sandstone	Connellsville sandstone	89+	-100±	Force pumps	20±	10+	Domestic	Three wells.
Near bottom	Limestone	Waynesburg or Uniontown limestone	------	-57	Manual, force pump	1-3	Ample	Domestic	Supplies two households.
38	Black shale	Cassville shale (?)	------	-25	Manual, force pump	1-3	25+ (?)	Domestic	Not plotted on Fig. 39; near well No. 375. Specific capacity about 2½ g. p. m. for each foot of drawdown.
75	Sandstone	Morgantown sandstone	29	—75	Manual, force pump	1-3	Ample	Domestic	Water from crevice of sandstone.
0	Jointed sandstone	Morgantown sandstone	------	------	Natural flow	------	3-5	Former resort	Spring.
Near bottom	Coarse sandstone	Saltsburg sandstone	------	—5	Gas lift formerly	------	110	Condensers cooling compressors	Frankfort compressing station. Aggregate yield of 6 wells reported as 650 g. p. m. in 1910.
Near bottom	------	Pittsburgh limestone ±	------	—30	Manual, force pump	1-3	Ample	Domestic	------
Near bottom	Sandstone and shale	Basal part of Monongahela formation	------	------	Manual, force pump	1-3	Not large	Domestic	------
0	Sandstone	Pittsburgh sandstone	------	------	Natural flow	------	5±	Roadside trough	Spring.
35	------	Morgantown sandstone (?)	43	------	None	------	5+	None	Peoples Natural Gas Co. No. 1934.
722	Sandstone	Connoquenessing sandstone	------	------	------	------	2½±	------	Salt water.
55	------	Connellsville sandtone	1,305	------	None	------	------	None	Peoples Natural Gas Co. No. 1573. Fresh water.
769	Sandstone	Kittanning sandstone ±	------	------	------	------	------	------	Salt water.
20	Top of limeston	Clarksburg limestone ±	------	------	None	------	------	None	No water from depth of 20 feet through Big Injun sand at 1,000+ feet.

No. on Fig. 39	Location: Nearest P. O.	Location: Distance and direction from P. O.	Owner or name	Topographic situation	Altitude above sea level	Depth of well	Diameter of well
					Feet	Feet	Inches
	Independence Township						
355	Avella	0	Avella Schoolhouse	Valley	925	100±	5⅝
	Jefferson Township						
342	Eldersville	¼ mi. W.	Jacob Dimit	Upland	1,275	92	5⅝
1049	Cross Creek	1½ mi. NW.	Alexander Walker	Valley	1,100	2,300	----------
			Gillespie heirs, No. 1	----------	1,285	2,126	----------
			Metcalf No. 1	----------	1,245	2,081	----------
			Kidd	----------	1,315	2,205	----------
	Morris Township						
384[b]	----------	----------	----------	Hillside	1,050	0	----------
			David Craft, No. 9	----------	1,055	3,210	----------
			Elmas Carey, No. 1	----------	1,130	2,725	----------
	Mount Pleasant Township						
346[a]	Hickory	0	Hickory High School	Summit	1,300	126	4¾
347	Hickory	1¾ mi. SE.	Adams Bros.	Valley	1,055	150	5⅝
1051	Hickory	1¼ mi. SW.	Donaldson	----------	1,140	700	----------
			Kinneman heirs	----------	1,285	1,236	----------
			D. C. Miller No. 1	----------	1,110	2,454	----------

Chief aquifer: Depth below surface	Chief aquifer: Character of material	Chief aquifer: Geologic horizon	Depth to which well is cased	Water level above (+) or below (—) surface	Method of lift	Capacity of pump	Rate of inflow	Use of water	Remarks
Feet			Feet	Feet		Gallons per minute	Gallons per minute		
Near bottom		Connellsville sandstone ±			Manual, force pump	1–3	Ample	Drinking	
Near bottom	Limestone	Benwood limestone	20–25		Manual, force pump	1–3	Ample	Domestic	
80	Limestone	Benwood limestone			None			None	Peoples Natural Gas Co. No. 1593. Fresh water.
1,066	Sandstone	Kittanning sandstone							Salt water.
1,511	Sandstone	Squaw sand							Salt water.
1,118	Sandstone	Kittanning or Homewood sandstone			None			None	
1,300	Sandstone	Burgoon sandstone					Large	None	Hole "full of water."
696	Sandstone	Saltsburg sandstone			None			None	
1,075	Sandstone	Kittanning sandstone					"Much"		
1,100	Sandstone	Kittanning sandstone			None		3½±	None	Salt water.
0	Sandstone	Jollytown coal ±			Natural flow		1½	Domestic, stock	Spring.
2,658	Sandstone	Gordon sand			None		½±	None	
1,520	Sandstone	Worthington sandstone			None			None	
100	Limestone	Union limestone	126	—100	Electric, force pump	10	10+	Drinking	Casing perforated at base. Maximum consumption 3,500 gallons a day. Another well near railroad station, 140 feet deep, entered Uniontown limestone without finding water.
Near bottom	Limestone and shale	Clarksburg limestone±			Force pump				
620	Sandstone	Saltsburg sandstone	352		None		Little	None	Salt water, cased off. Shuts off fresh water at Clarksburg limestone±.
			1,183						Shuts off salt water at Kittanning sandstone.
1,430	Sandstone	Burgoon sandstone			None		Little	None	

No. on Fig. 39	Location: Nearest P. O.	Location: Distance and direction from P. O.	Owner or name	Topographic situation	Altitude above sea level	Depth of well	Diameter of well
					Feet	Feet	Inches
	North Strabane Township		Bella Lyle	----------	1,295	3,119	----------
			Williams No. 1	----------	1,050	2,597+	----------
	Nottingham Township						
1055	Kammerer	2 mi. NW.	D. R. McClure	Hillside	1,175	2,340	6¼
1056	Kammerer	½ mi. W.	J. Barr	Summit	1,200	2,818	10–6¼
	Peters Township						
351	Lawrence	1½ mi. S.	William Strange	Terrace	1,140	90	5⅝
352	Lawrence	1½ mi. E.	Thomas Denniston	Hillside	1,075	150	5⅝
353	Lawrence	2½ mi. SE.	George Schnuth	Hillside	1,050	85±	5⅝
354	Venetia	0	Venetia Schoolhouse	Valley	1,010	199	5⅝
1052	Venetia	2⅔ mi. NE.	E. B. Phillips	Valley	1,100	2,730	10–6¼
1053	Venetia	1½ mi. N.	E. E. & J. Beabout	Valley	1,075	2,625	10–6¼
1054	Venetia	¾ mi. W.	Mary E. and M. M. Bryant	Valley	1,050	3,628	10–6⅝
			W. W. Smith No. 2	----------	1,045	2,559	----------

Chief aquifer			Depth to which well is cased	Water level above (+) or below (—) surface	Method of lift	Capacity of pump	Rate of inflow	Use of water	Remarks
Depth below surface	Character of material	Geologic horizon							
Feet			Feet	Feet		Gallons per minute	Gallons per minute		
1,300	Coal	Lower Kittanning coal			None			None	
2,415	Sandstone	Fifty-foot sand							Salt water.
1,295	Sandstone	Homewood sandstone			None			None	
30		Waynesburg sandstone±	2,351		None			None	Peoples Natural Gas Co. No. 1807. Fresh water.
80	Coal	Waynesburg coal							Fresh water.
967		Buffalo sandstone±							Salt water.
1,146		Freeport sandstone±							Salt water.
150		Benwood limestone±	1,568		None		2½	None	Peoples Natural Gas Co. No. 1820. Fresh water.
1,120	Top of coal	Lower Kittanning coal							
55	Sandstone	Waynesburg sandstone (?)		—30	Manual, force pump	1-3	½—	Domestic	
37		Waynesburg sandstone±			Manual, force pump	1-3	1	Domestic	
57		Waynesburg limestone (?)							
75	Black shale	Benwood limestone±	45		Manual, force pump	1-3	3±	Domestic	Iron-bearing water encountered 32 and 45 feet below the surface was cased off.
190	Shale (?)	Clarksburg limestone±	100±	—140	Manual, force pump	1-3	Ample	Domestic	
80		Fishpot limestone±	104		None		3(?)		Peoples Natural Gas Co. No. 1443. Fresh water.
203	Top of coal	Pittsburgh coal					25+		
1,183	Sandstone	Homewood sandstone					2±		
320	Sandstone	Connellsville sandstone	1,360		None		1½±		Peoples Natural Gas Co. No. 1759.
975	Base of coal	Lower Kittanning coal (?)					1½±		
80		Pittsburgh sandstone±	1,334		None			None	Peoples Natural Gas Co. No. 1806. Fresh water.
620	Sandstone	Buffalo sandstone							Fresh water.
700	Sandstone	Freeport sandstone							Fresh water.
2,200	Sandstone	Fifty-foot sand			None			None	Salt water.

No. on Fig. 39	Location: Nearest P. O.	Location: Distance and direction from P. O.	Owner or name	Topographic situation	Altitude above sea level	Depth of well	Diameter of well
					Feet	Feet	Inches
	Robinson Township						
330	Joffre	3¾ mi. N.	West Penn Water Co.	Valley	910	90	10
331[a]	Midway	¼ mi. N.	S. G. Beabout	Valley	1,100	60	5⅝
332[a]	Midway	¼ mi. E.	Carnegie Coal Co.	Valley	1,060	48	6¼
1045	Tyre	4 mi. W.	Moody	Upland	1,200	1,000+	----------
1046	Midway	2½ mi. N.	R. A. Geary	Valley	1,050	7,248	13–4¼
1047	Midway	1¾ mi. N.	R. E. Dowler	Summit	1,200	2,214	10–6⅝
	Smith Township						
333[a]	Burgettstown	¼ mi. W.	Burgettstown Coal Co.	Hillside	1,050	82–90	6⅝
334	Burgettstown	¾ mi. NE.	P. C. C. and St. L. RR.	Valley	975	125±	8¼
335	Joffre	0	Shean Coal Co.	Hillside	1,000	110	5⅝
336[a]	Burgettstown	½ mi. S.	Henry Tennyson	Hillside	1,020	85±	5⅝
337	Bulger	¼ mi. S.	Bulger Schoolhouse	Hillside	1,180	82	8¼

Chief aquifer: Depth below surface	Chief aquifer: Character of material	Chief aquifer: Geologic horizon	Depth to which well is cased	Water level above (+) or below (—) surface	Method of lift	Capacity of pump	Rate of inflow	Use of water	Remarks
Feet			Feet	Feet		Gallons per minute	Gallons per minute		
75	White sandstone	Saltsburg sandstone	14	—7	Steam, force pump	100±	50+	Emergency municipal supply	Yield from two wells reported 125,000 gallons a day. Located ¾ mile northeast of village of Bavington.
Near bottom	Limestone	Lower Pittsburgh limestone	38	—36	Manual, force pump	1–3	Ample	Domestic	----------
40	Sandstone	Connellsville sandstone	40	+1	Electric, suction pump	25	25+	Domestic	Supplies miners' dwellings at Midway mine.
150	Friable sandstone	Connellsville sandstone	----------	—50	None	----------	Large	None	Fresh water, cased off.
600	Base of coal	Lower Kittanning coal	7,214	----------	None	----------	----------	None	Peoples Natural Gas Co. No. 770. Well enters Clinton formation.
6,045	Gray sandstone	Ridgeley sandstone (Oriskany)	----------	----------	----------	----------	----------	----------	----------
6,260	Brown sandstone	Oriskany or Helderberg	----------	—700(?)	----------	----------	----------	----------	----------
6,520	White sandstone	Helderberg formation	----------	----------	----------	----------	----------	----------	----------
120	----------	Morgantown sandstone(?)	----------	----------	None	----------	----------	None	Peoples Natural Gas Co. No. 2088. Fresh water.
550	Coal	Upper Freeport coal	----------	----------	----------	----------	----------	----------	----------
723	Coal	Lower Kittanning coal	----------	----------	----------	----------	----------	----------	----------
988	Sandstone	Homewood sandstone	----------	----------	----------	----------	----------	----------	----------
70–75	Red shale	Lower Pittsburgh limestone±	23–29	----------	Manual, force pumps	1–3	Ample	Domestic	Miners' dwellings at Dinsmore mine.
90	Sandy shale	Morgantown sandstone(?)	14	----------	Air lift	----------	Large	Formerly locomotive boilers	Superseded in 1925 by surface water supply.
Near bottom	Sandstone	Connellsville sandstone	----------	----------	Force pumps	----------	Ample	Domestic	Wells at miners' dwellings.
70	Red shale	Lower Pittsburgh limestone±	----------	—50±	Manual, force pump	1–3	Ample	Domestic	----------
70	Shale	Pittsburgh sandstone±	20	----------	Electric, force pump	----------	Small	Drinking	----------

No. on Fig. 39	Location: Nearest P. O.	Location: Distance and direction from P. O.	Owner or name	Topographic situation	Altitude above sea level	Depth of well	Diameter of well
					Feet	Feet	Inches
	Smith Township—Continued						
338	Bulger	½ mi. SE.	Ben Lewis	Upland	1,275	106	5⅝
339	Slovan	1 mi. NW.	American Zinc and Coal Co.	Hillside	1,185-1,200	84–112	5⅝
340	Slovan	0	Adolph Horovitz	Valley	1,020	58	5⅝
341	Cherry Valley	0	Miscellaneous	Valley	1,040	48–150	5⅝
1048	Bulger	1¼ mi. NW.	Julian Stopczrenski	Ridge crest	1,170	2,048	10–6⅝
			Beck, No. 1	----------	----------	1,933+	----------
	Somerset Township						
373	Eightyfour	0	Grange Hall	Valley	1,000±	52	5⅝
	South Franklin Township						
383	Washington	3½ mi. S.	Warren F. Vankirk	Hillside	1,350±	90	5⅝
			Dennis Wiley, No. 1	----------	----------	3,243	----------
			Elliott, No. 2	----------	----------	2,795	----------
			J. H. Vankirk, No. 5	----------	----------	2,856	----------
	South Strabane Township						
372[a]	Washington	2 mi. SE.	Miscellaneous	Hilltop	1,365–1,400	43–103	5⅝

Chief aquifer			Depth to which well is cased	Water level above (+) or below (—) surface	Method of lift	Capacity of pump	Rate of inflow	Use of water	Remarks
Depth below surface	Character of material	Geologic horizon							
Feet			Feet	Feet		Gallons per minute	Gallons per minute		
100	Limestone	Redstone limestone			Manual, force pump	1-3	Ample	Domestic	
80	Shale	Above Benwood limestone			Manual, force pump	1-3	Ample		Former domestic supply at laborers' dwellings at Lanceloth.
40	Shale	Below Fishpot limestone			Manual, force pump	1-3	Ample	Domestic	Other wells in community from 40 feet deep in valley to 165 feet deep near schoolhouse on hilltop. Some yields very small.
	Limestone	Redstone limestone±			Manual, force pumps	1-3	Ample	Household	
40	Limestone	Redstone limestone	1,370		None		7	None	Peoples Natural Gas Co. No. 1893.
590	Sandstone	Mahoning sandstone					$2\frac{1}{2}$		
925	Sandstone	Homewood sandstone					$1\frac{1}{2}$		Hole "full of water" at 975 feet.
1,388	Sandstone	Burgoon sandstone					$\frac{1}{4}$		
464	Sandstone	Morgantown sandstone			None			None	
1,140	Sandstone	Homewood sandstone							
38	Sandstone	Waynesburg sandstone	20	—35	Manual, force pump	1-3	Ample	Drinking	
Near bottom	Shale	Fish Creek sandstone ±	20±	—60	Manual, force pump	1-3	Very small	Drinking	Inadequate for all household uses.
800	Sandstone	Morgantown sandstone			None		$7\frac{1}{2}$±		
1,610	Sandstone	Homewood sandstone					Large		Hole "full of water."
2,510	Sandstone	Gantz sand					$\frac{1}{2}$±		
2,742	Sandstone	Gordon sand					1±		
90		Lower Washington limestone ±			None			None	
1,515	Sandstone	Homewood sandstone							
1,780	Sandstone	Burgoon sandstone			None			None	
Near bottom	Limestone and shale	Donley limestone ±	18-25	-20 to 40	Manual, force pumps	1-3	Ample	Household	Village of Laboratory. Water sample from schoolhouse well.

No. on Fig. 39	Location: Nearest P. O.	Location: Distance and direction from P. O.	Owner or name	Topographic situation	Altitude above sea level	Depth of well	Diameter of well
					Feet	Feet	Inches
	Speers Borough						
377	Dunlevy	1 mi. W.	Kittle	Hillside	975	175	5⅝
378	Dunlevy	1¼ mi. W.	Russell Sutherland	Terrace	930	75±	5⅝
	Union Township						
18	Elrama	¼ mi. NW.	Equitable Gas Co.	Stream plain	750±	50±	12
358	Finleyville	1½ mi. NW.	Mineral Beach, No. 1	Valley	1,050	438	8–6¼
359	Finleyville	1½ mi. NW.	Mineral Beach, No. 2	Valley	1,050	790	8–6¼
360[a], [b]	Finleyville	⅝ mi. N.	H. D. Benn	Valley	1,010	44	5⅝
361	Elrama	0	Equitable Gas Co.	Terrace	820–850	67–98	6
362	Courtney	1 mi. N.	Diamond Coal Co.	Valley	850	153	8
363	Courtney	1¼ mi. SW.	A. K. Colson	Valley	800	97	5⅝
			C. Fritchman, No. 1	----------	950	1,965+	----------
	Washington Borough						
368[a]	Washington	----------	Washington Ice Co.	Valley	1,030	200±	6¼
369	Washington	Jefferson Avenue	Washington Baking Co.	Valley	1,030	100	6¼
370	Washington	Beau St.	Brewery	Valley	1,025±	365	6¼
371	Washington	----------	Earl Casto	Hillside	1,170	105	5⅝

Chief aquifer: Depth below surface	Chief aquifer: Character of material	Chief aquifer: Geologic horizon	Depth to which well is cased	Water level above (+) or below (—) surface	Method of lift	Capacity of pump	Rate of inflow	Use of water	Remarks
Feet			Feet	Feet		Gallons per minute	Gallons per minute		
Near bottom	Clayey shale	Lower Pittsburgh limestone ±	20±	—140	Gasoline, force pump		5±	Domestic, stock	
70	White sandstone	Connellsville sandstone			Manual, force pump	1–3	Ample	Domestic	
Near bottom	Sand and gravel	Alluvium	To bottom			100±	100+	Industrial	Lower 5 feet of casing perforated with ½-inch drilled holes.
50	Limestone								Cased off.
180	Sandy shale (?)	Morgantown sandstone	100	—35±	Electric, force pump	65	65	Swimming pool	
690	Sandstone	Kittanning sandstone ±	300		Electric, force pump	35	35	Swimming pool	Brackish water. Not plotted on Fig. 39; near No. 358.
40±		Connellsville sandstone±		+1	Automatic electric, suction pump	2	2+	Domestic	Natural flow ½ g. p. m.
Near bottom	Shale	Clarksburg limestone		-35 to 50	Manual, force pumps	1–3	3+	Domestic	Employees' dwellings, 5 families per well.
		Fishpot limestone ±			None		5±	None	Originally for boiler feed.
Near bottom	Shale	Lower Pittsburgh limestone ±	35		Manual, force pump	1–3	Ample	Domestic	Map location uncertain.
1,000		Kittanning sandstone ±			None			None	Salt water.
185±	Friable sandstone	Sewickley sandstone	30	—60	Air lift	25	25+	Condensers	Representative of three wells. Pumped steadily during summer months.
Near bottom	Shale	Waynesburg or Uniontown limestone ±	28	—25			5+	Bakery	Not plotted on Fig. 39. Near No. 368.
Near bottom	Coal	Pittsburgh sandstone and coal	20	—5			5+	Formerly condensers	Not plotted on Fig. 39. Near No. 368.
Near bottom	Limestone (?)	Lower Washington limestone			Manual, force pump	1–3	Ample	Domestic	

No. on Fig. 39	Location		Owner or name	Topographic situation	Altitude above sea level	Depth of well	Diameter of well
	Nearest P. O.	Distance and direction from P. O.					
					Feet	Feet	Inches
	West Bethlehem Township						
394	Marianna	$3\frac{3}{4}$ mi. NW.	Geaman Schrontz	Upland	1,275	140	$5\frac{5}{8}$
395	Marianna	2 mi. W.	Franklin Schoolhouse	Hillside	975	95	$5\frac{5}{8}$
396	Marianna	$\frac{1}{2}$ mi. SW.	Angeline Manaokoff	Terrace	950	87	$5\frac{5}{8}$
	West Pike Run Township						
20	Daisytown	0	Vesta Coal Co.	Valley	950	25-30	$5\frac{5}{8}$
397	Beallsville	$1\frac{1}{2}$ mi. SE.	Mike Koehes	Upland	1,210	95	$5\frac{5}{8}$
398	Daisytown	0	Vesta Coal Co.	Valley	950	141	$5\frac{5}{8}$
399	Daisytown	$\frac{1}{2}$ mi. SW.	Taylor C. Pepper, No. 2	Hillside	1,050	156	5

[a] Analysis of water by United States Geological Survey.
[b] Flowing well or spring.

Chief aquifer			Depth to which well is cased	Water level above (+) or below (—) surface	Method of lift	Capacity of pump	Rate of inflow	Use of water	Remarks
Depth below surface	Character of material	Geologic horizon							
Feet			Feet	Feet		Gallons per minute	Gallons per minute		
100±	Shale	Middle Washington limestone±	----	----	Manual, force pump	1-3	1±	Domestic	----
85	Shale	Washington sandstone±	----	—25	Manual, force pump	1-3	Large	Drinking	----
45	Sandstone	Waynesburg sandstone	27	—45	Manual, force pump	1-3	Ample	Household	----
Near bottom	Sand and gravel	Alluvium	[illegible]	----	Manual, force and suction pumps	1-3	Ample	Domestic	Company dwellings on Pike Run. Located near No. 398. Abandoned.
80	Limestone	Waynesburg limestone	22	—80	Manual, force pump	1-3	Ample	Domestic	Ritchieville.
115	Sandstone	Morgantown sandstone	40	—100	Manual, force pump	1-3	3±	Domestic	Supplies about 15 dwellings by careful use.
137	Limestone	Lower Pittsburgh limestone	127	—75±	Air lift	----	5+	Domestic, stock	No. 1 well at house, 233 feet deep without water.

Driller's log of Sam Ofsay well at Hills

(No. 349, Fig. 39.)

	Thickness (Feet)	Depth (Feet)
Clay, yellow	25	0–25
Clay, blue	8	25–33
Limestone	4	33–37
Shale, gray (Waynesburg limestone)	5	37–42
Shale, carbonaceous	4	42–46
Limestone	2	46–48
Shale, carbonaceous (Uniontown coal)	1	48–49
Limestone and shale, interbedded, water at base (Uniontown limestone)	5	49–54
Limestone	6	54–60
Shale, water at base	7	60–67
Sandstone and shale, interbedded	13	67–80

Driller's log of J. F. Steele well near Florence

(No. 1,042, Fig. 39.)

	Thickness (Feet)	Depth (Feet)
Rock waste, $3\frac{1}{2}$ gallons water per minute at base	35	0– 35
Conemaugh formation:		
Coal (Harlem)	$1\frac{1}{2}$	35– $36\frac{1}{2}$
Shale and limestone	$38\frac{1}{2}$	$36\frac{1}{2}$– 75
Sandstone (Saltsburg)	15	75– 90
Shale	153	90– 243
Sandstone (Buffalo)	17	243– 260
Sandstone	39	260– 299
Allegheny formation:		
Coal (Upper Freeport)	2	299– 301
Shale	75	301– 376
Sandstone (Freeport)	79	376– 455
Shale	73	455– 528
Coal (Lower Kittanning±)	4	528– 532
Shale and limestone (Vanport)	35	532– 567
Sandstone (Clarion or "Gas")	8	567– 575
Shale and limestone (?), interbedded	50	575– 625
Pottsville formation:		
Sandstone (Homewood or "Salt")	55	625– 680
Shale and sandstone, interbedded (Mercer)	42	680– 722
Sandstone (Connoquenessing) $2\frac{1}{2}$ gallons salt water per minute	48	722– 770
Shale and sandstone, interbedded	40	770– 810
Pocono formation:		
Sandstone	85	810– 895
Shale (Burgoon)	60	895– 955
Sandstone	133	955–1,088
Shale and sandstone, interbedded	62	1,088–1,150
Sandsotne (Squaw sand)	36	1,150–1,186
Shale and sandstone	101	1,186–1,287

Note. Peoples Natural Gas Co.'s well No. 1,934.

Driller's log of Donaldson well near Midway

(Located 1¼ miles S. E. of well No. 1,047, Fig. 39.)

	Thickness (Feet)	Depth (Feet)
Soil	5	0– 5
Conemaugh formation:		
Shale, yellow, fresh water at 15 feet	16	5– 21
Limestone (Lower Pittsburgh)	8	21– 29
Shale, large yield of water	11	29– 40
Shale, gray	91	40– 131
Shale, red	19	131– 150
Shale, gray	54	150– 204
Limestone, cream-colored	16	204– 220
Shale, carbonaceous	55	220– 275
Coal (Harlem)	5	275– 280
Shale, gray	60	280– 340
Limestone, cream-colored (Woods Run?)	20	340– 360
Sandstone, white	5	360– 365
Shale, gray	5	365– 370
Shale, red	20	370– 390
Limestone, white	50	390– 430
Shale, gray	28	430– 458
Limestone, white	12	458– 470
Shale, gray	4	470– 474
Limestone, white (Brush Creek?)	36	474– 510
Shale, red ("pink rock")	21	510– 531
Sandstone, light gray (Mahoning)	51	531– 582
Allegheny formation (plane of separation indefinite):		
Shale, gray	3	582– 585
Limestone, white } (Upper Freeport coal and limestone?)	15	585– 600
Shale, carbonaceous } (Upper Freeport coal and limestone?)	10	600– 610
Limestone, white } (Upper Freeport coal and limestone?)	22	610– 632
Shale, carbonaceous	10	632– 642
Coal (Lower Freeport)	4	642– 646
Sandstone, dark (Freeport)	54	646– 700
Shale, carbonaceous	25	700– 725
Limestone, white	17	725– 742
Sandstone (Worthington? or "Gas" sand) salt water at 763 feet	38	742– 780
Limestone, brown	20	780– 800
Limestone, buff	20	800– 820
Sandstone, dark	9	820– 829
Shale, gray	9	829– 838
Limestone, white	27	838– 865
Allegheny and Pottsville formations (Plane of separation divides sandstone below.):		
Sandstone (Clarion + Homewood or Salt), salt water at 950 feet	105	865– 970
Coal (Mercer)	3	970– 973
Limestone, white	10	973– 983
Sandstone, white (Connoquenessing?)	29	983–1,012
Mauch Chunk formation (?):		
Shale, carbonaceous	7	1,012–1,019
Shale, gray	6	1,019–1,025
Shale, carbonaceous	15	1,025–1,040
Limestone (Greenbrier or Little lime)	11	1,040–1,051
Shale, carbonaceous	4	1,051–1,055
Pocono formation:		
Sandstone (Burgoon, Big Injun sand), yellow, ½ gallon salt water per minute at 1,096	329	1,055–1,384
Shale and sandstone, interbedded	81	1,384–1,465
Sandstone, white } (Squaw sand)	16	1,465–1,481
Sandstone, dark gray } (Squaw sand)	22	1,481–1,503
Shale and sandstone, interbedded	134	1,531–1,665
Sandstone, white	11	1,520–1,531
Shale and sandstone, interbedded	134	1,531–1,665
Sandstone (Berea) } (Murrysville sand)	30	1,665–1,695
Shale, dark } (Murrysville sand)	16	1,695–1,711
Sandstone } (Murrysville sand)	18	1,711–1,729
Shale and sandstone, interbedded } (Murrysville sand)	17	1,729–1,746
Sandstone, white } (Murrysville sand)	38	1,746–1,784
Shale, dark } (Murrysville sand)	10	1,784–1,794
Sandstone, white } (Murrysville sand)	16	1,794–1,810

Driller's log of Donaldson well—Continued

	Thickness (Feet)	Depth (Feet)
Catskill formation:		
Shale and sandstone, interbedded	40	1,810-1,850
Shale, red ("pink rock")	44	1,850-1,894
Sandstone, white (Gantz)	6	1,894-1,900
Shale, dark	23	1,900-1,923
Sandstone (Fifty-foot)	28	1,923-1,951
Shale and sandstone, interbedded, water at 1,960	90	1,951-2,041
Sandstone (Nineveh)	4	2,041-2,045
Shale	51	2,045-2,096
Sandstone (Gordon stray)	7	2,096-2,103
Shale	34	2,103-2,137
Sandstone (Gordon)	5	2,137-2,142
Shale	84	2,142-2,226
Sandstone, dark (Fourth)	7	2,226-2,233
Shale	5	2,233-2,238
Sandstone, dark (Fifth)	29	2,238-2,267
Shale	117	2,267-2,384

Note. Peoples Natural Gas Co. well No. 2,025.

WESTMORELAND COUNTY

TOPOGRAPHY AND DRAINAGE

Westmoreland County is divisible into two physiographic districts by a line which trends N.30°E. through Derry and Mammoth and passes about 2½ miles southeast of Latrobe. To the west of this line is the dissected Allegheny peneplain, the Kanawha section of the Appalachian Plateaus. The Kanawha section at a distance from the major streams, is an assemblage of sub-mature rounded hills or ridges and open valleys of somewhat rounded contour. The summit elevations are approximately accordant and, from a minimum of 1,250 to 1,400 feet above sea level at the northern extremity of the county increase very gradually southward and eastward to a maximum slightly more than 1,500 feet above sea level, which is attained by a knob about 4½ miles west of Scottdale. The local relief is 250 to 350 feet. The major streams however, occupy more youthful trenches which are cut 400 to 650 feet below the ridge crests. The extreme relief within this district is 775 feet. On the east, the dissected peneplain abuts against a series of bold strike ridges which rise 1,200 feet or more above the Allegheny erosion surface. These constitute the Allegheny Mountains section of the Appalachian Plateaus. The most westerly of these ridges, Chestnut Ridge, strikes N.30°E. entirely across the county and is pierced by only two streams in the distance of 22 miles. Its crest ranges in altitude from 2,625 to 1,645 feet above sea level. About 9 miles east of Chestnut Ridge and parallel to it is Laurel Hill, whose crest ranges in elevation between 2,620 and 2,945 feet above sea level. This ridge bounds the county on the east and is pierced only by Conemaugh River. The terrane between these two ridges is intricately and sub-maturely dissected. Its summits range from 1,500 to 1,900 feet above sea level and its drainage ways are cut to an elevation of 1,100 to 1,300 feet above sea level. The greatest local relief within this portion of the county is 1,620 feet, at the Conemaugh River gap through Laurel Hill. The extreme relief for the entire county is approximately 2,200 feet.

Westmoreland County occupies the greater part of the terrane enclosed by the widespread limbs of a U-shaped drainage way which comprises Kiskiminetas and Allegheny rivers on the north and Mononga-

hela and Youghiogheny rivers on the west and south. Within this drainage way the Kanawha section is drained radially from a center about 3 miles north of Greensburg—northward by Loyalhanna Creek and Beaver Run, westward to Monongahela River by Turtle Creek and to Youghiogheny River by Sewickley and Jacobs creeks. These streams and their secondary tributaries form a most closely knit drainage pattern. The greater part of the Allegheny Mountains secti n within the county is drained by subsequent strike valleys into Conemaugh River and Loyalhanna Creek. A small area in the extreme southeastern corner of the county drains southward by Indian Creek into Youghiogheny River.

AREAL GEOLOGY

The sedimentary rocks which crop out in Westmoreland County (See Pl. I) range in age from middle Pocono on the east to middle Washington along the western boundary, the composite stratigraphic column having a maximum thickness of 2,400 feet. The column is interrupted by one major break, the unconformity which separates the Mauch Chunk and Pottsville formations. Full sections of the Allegheny, Conemaugh, and Monongahela formations are exposed. The oldest beds, the basal portion of the Burgoon sandstone, crop out on the crest of Laurel Ridge in the east-central part of the county and in the Loyalhanna Creek gap through Chestnut Ridge southeast of Latrobe. The youngest exposed strata, which lie just above the horizon of the Lower Washington limestone, cap the highest hills of the Port Royal syncline (Pl. 1) between Herminie and Irwin. The beds of the Washington formation crop out only on the hilltops of the deepest portions of the Port Royal, Greensburg, and Latrobe synclines in the southwestern quadrant of the county. The underlying Monongahela formation crops over large areas in these same troughs and also caps a few scattered summits in the Duquesne syncline to the northwest and in the Ligonier syncline of the Allegheny Mountains section. The Conemaugh formation is by far the most extensive of the Carboniferous formations within the county, and covers the entire Kanawha section with the exception of the deepest parts of the structural troughs and a few scattered outcrops of older rocks at the anticlinal axes. Farther east, it crops in a band 5 to 7 miles wide in the Ligonier syncline. In the Kanawha section the Allegheny formation has a narrow outcrop in the lower Kiskiminetas and Allegheny valleys. Further, it crops over small areas along the crest of the Grapeville (Jacksonville) anticline in the lower valleys of Conemaugh River and of Loyalhanna Creek, also along the crest of the Fayette anticline in the Sewickley Creek valley at Hunkers, in Barren Run about 2 miles south of Mendon, and in the valley of Jacobs Creek. At the last locality the uppermost beds of the Pottsville formation are also exposed. The principal outcrop areas of the Allegheny and underlying formations lie along Chestnut Ridge and Laurel Hill, each formation being exposed in a most sinuous band along the flanks and across the crests of these topographic eminences, which are partially stripped anticlines. These consolidated sediments are overlain in the major valleys by unconsolidated deposits of the Carmichaels formation and of alluvium.

GEOLOGIC STRUCTURE

The consolidated sediments in Westmoreland County are deformed by a number of sub-parallel folds whose axes strike N.25-50° E., as shown by contour lines drawn on the accompanying map (Pl. I) as though on the base of the Pittsburgh coal. In the northwestern part of the county the folds are open symmetrical structures whose flanks dip less than 2° and whose axes plunge southwestward about ½°. They are, in order from the west, Duquesne syncline, Murrysville anticline, and Bellevernon anticline. East of these lies the Port Royal-Elders Ridge syncline, an asymmetrical fold whose axial plane dips 1½° E. Its axis—which passes through Fitzhenry Borough in the Youghiogheny Valley and trends northeastward through Manor, a mile east of Export, and 2 miles west of Saltsburg—marks the western boundary of a second structural province whose folds are closer and deeper and whose principal axes, though gently undulatory, are essentially horizontal within the county. The most westerly—the Grapeville (Jacksonville) anticline, Greensburg syncline, Fayette anticline, and Latrobe syncline—display a relatively constant amplitude of 1,050 feet, the index stratum attaining an elevation of 1,800 to 1,850 feet above sea level on the crests and declining to a minimum altitude of 800 feet above sea level in the troughs. These are symmetrical and somewhat canoe-shaped folds whose flanks have a maximum dip of approximately 7°. From an elevation of 800 feet in the Latrobe basin, the index stratum rises eastward to an altitude of 3,400 feet on Chestnut Ridge anticline, drops to an altitude of 1,500 feet in the Ligonier basin, and rises to a maximum of slightly less than 4,500 feet above sea level on the crest of Laurel Hill anticline. On the flanks of these symmetrical folds the rocks attain a dip of 12°, the greatest within the county. Since the post-Mauch Chunk beds are conformable throughout and have been similarly folded, it follows that the deformation of a given water-bearing stratum is the same as that of the index bed and, consequently, may be read directly from the map (Pl. I). Further, the angular discordance between the post-Mauch Chunk and the subjacent formations is so slight that no appreciable error attaches to reading from the map the difference in elevation of any given bed between two adjacent well sites.

GROUND WATER RESOURCES

General features

Given its relatively great thickness of exposed rocks, its wide range in topographic forms, and its two structural provinces, Westmoreland County exhibits a very wide range in the conditions of ground water occurrence. In the Kanawha section the few springs are small and most household water supplies are won from drilled wells. Although few wells are wholly unsuccessful, it is impossible in many districts in which the rocks are dominantly shaly to develop yields of more than 5 gallons per minute. Over by far the greater part of this district the uppermost salt water is found in the Clarion sandstone, near the base of the Allegheny formation or in the Pottsville sandstones below, but

inasmuch as its static level is usually below that of the fresh water aquifers throughout the petroliferous districts, contamination of the fresh water is not likely to occur. In the Allegheny Valley, however, these members are not deeply buried, as in well 407 of Allegheny Township (Fig. 40). In general it may be stated that any well more than 500 feet deep, or any which passes more than 50 or 100 feet below the level of the major streams in the Kanawha section will find only salt water. Furthermore, any well more than 250 feet deep is likely to yield saline water. So far as is known, fresh ground waters do not exist in any stratum beneath the uppermost salt water aquifer. In the Allegheny Mountains section, on the other hand, deep erosion of the more closely folded rocks has exposed a thick succession of permeable beds. These beds are usually saturated with water which is in transit to the true water table and hence supply a very large number of springs, many of which are of fourth magnitude. Inasmuch as the district is not densely populated and is essentially rural, it has been possible in a great many instances to locate dwellings adjacent to spring sites so that the problems of water supply are not acute. Fewer wells have been drilled than in the less rugged district to the west, although the older rocks of the Allegheny Mountains section offer many potential aquifers which yield potable waters several hundred feet below regional drainage level.

Those stratigraphic units which are known to be sources of fresh water within the county are embodied in the subjoined table, together with citations to the pages on which the water-bearing properties of each are discussed at some length. Of these the outstanding are the unconsolidated deposits and the sandstone strata. In other portions of the section ground water occurs in bedding plane conduits of small magnitude where the beds are not deeply buried, but is not usually obtainable where the beds pass beneath thick continuous cover. The quality of the ground waters is shown by the analyses of typical samples which are tabulated on pages 77-79. The quality is treated further in the descriptions of the several water-bearing members to which reference has been made. Artesian conditions exist in the more deeply folded rocks of the eastern portion of the county, as noted on pages 67-69.

Sources of fresh water in Westmoreland County

Formation and member	Pages of the report
Alluvium	111
Carmichaels formation	125
Washington formation:	
Waynesburg "A" coal and associated beds	141
Cassville shale	144
Monongahela formation:	
Waynesburg limestone	146
Uniontown sandstone	147
Uniontown and Benwood limestones	148
Fishpot limestone	152
Redstone limestone	153
Pittsburgh sandstone	154
Conemaugh formation:	
Pittsburgh limestones	157
Connellsville sandstone	159
Clarksburg limestone	160
Morgantown sandstone	163
Berlin coal and associated rocks	169
Ames limestone	169
"Pittsburgh Reds"	169
Saltsburg sandstone	170
Bakerstown coal	174
Buffalo sandstone	175
Cambridge limestone	177
Brush Creek coal	177
Mahoning sandstone	178
Allegheny formation:	
Upper Freeport limestone and accompanying rocks	185
Butler sandstone	184
Lower Freeport coal and associated beds	185
Freeport sandstone	186
Worthington sandstone	187
Kittanning sandstone	189
Vanport limestone	190
Clarion sandstone	191
Pottsville formation:	
Homewood sandstone	193
Connoquenessing sandstone	196
Pocono formation:	
Burgoon sandstone	198

The alluvium and glacial outwash of the Allegheny Valley and other major drainage ways is the one source of large water supplies for industrial purposes. Adequate methods of constructing and finishing wells in these unconsolidated deposits have been discussed early in this book.

At many places in the coal fields of the Port Royal, Greensburg, and Latrobe synclines, and of the Allegheny Valley, the beds above the coal have been drained by mining and the beds below the coal contain water that is concentrated in iron. Hence, it may be impossible to obtain a supply of ground water of satisfactory quality and rural supplies may be obtained from rain catches and cisterns. In some parts of these coal fields wells of small capacity are drilled to semiperched bodies of water in the Uniontown and Benwood limestones and other strata in preference to deeper drilling and the chance of obtaining a dry hole or water of unsatisfactory quality.

In the Allegheny Valley it is likely that salt water will be encountered in wells that are drilled below the Upper Freeport coal or more than 50 or 100 feet below drainage level.

Municipal supplies

Derry. The city of Derry (population 3,046), in the eastern part of the county, is supplied in part by ground water discharged by Ethel Spring (No. 441, Fig. 40) and impounded in a 156,000,000-gallon storage reservoir. The spring, which forms the permanent head of a tributary of McGee Run, is located a quarter of a mile west of the borough at an altitude of 1,165 feet above sea level. The water-bearing stratum occupies the approximate horizon of the Ames limestone. Water escapes from many small openings scattered over a third of an acre, the yield being variable but averaging about 25 gallons a minute. During periods of extreme drought the yield is very small although persistent. The surface drainage area above the spring is about 40 acres, the direct run-off from which constitutes the greater portion of the impounded supply.

West Newton. The municipal water supply of West Newton, which has a population of 2,953, is obtained from a group of 12 drilled wells located along the east bank of Youghiogheny River at the southwest corner of the borough. These wells (No. 480, Fig. 40) are 6 inches or 8 inches in diameter and about 200 feet deep. They tap the Connellsville sandstone. Each well is equipped with a double-acting deep well force pump driven by an electric motor. The yield of each is 20 to 25 gallons per minute, although the correlative drawdown and, consequently, the specific capacity are not known.

From the wells, the water flows by gravity to a gathering basin beneath the pump house, from which it passes through a 6-inch force main to a 1,000,000-gallon distributing reservoir on a hilltop at the southeast corner of the borough. The high pressure pumps are one Ramsey and one Gould, each with a rated capacity of 200 gallons per minute. The reservoir is at an altitude of 1,025 feet above sea level, and about 250 feet above the well site. Distribution is by gravity through 5.3 miles of mains, 10-inch to 4-inch in size. The average daily consumption is about 150,000 gallons, of which a third is by minor industries. The quality of the water is shown by the analysis of sample No. 480 tabulated on page 78 and discussed on page 160.

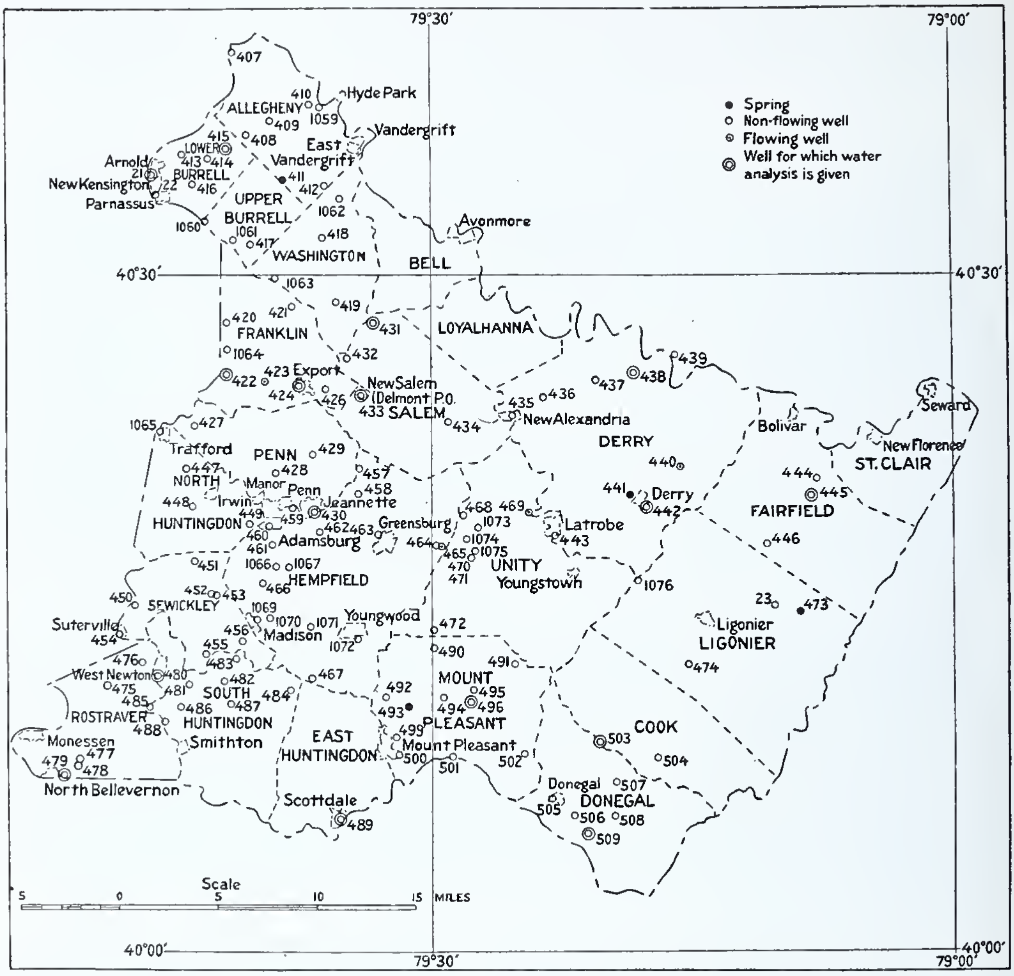


Figure 40. Map of Westmoreland County showing the location of wells and springs described in this report.

The following table of typical wells and springs in Westmoreland County is too wide to set crosswise of two facing pages. Therefore rules have been inserted to separate townships and boroughs and by using them as guides the information concerning a given well can easily be traced from the left hand page to the right hand page.

TYPICAL WELLS AND SPRINGS IN WESTMORELAND COUNTY, PA.

No. on Fig. 40	Location: Nearest P. O.	Location: Distance and direction from P. O.	Owner or name	Topographic situation	Altitude above sea level	Depth of well	Diameter of well
					Feet	Feet	Inches
	Adamsburg Borough						
460	Adamsburg	0	----------	Saddle	1,175	290	5⅝
	Allegheny Township						
407	Ingleside	0	Carnegie Farm	Valley	825	225	----------
408	Braeburn	2 mi. SE.	Melwood Park	Valley	985	55	6
409	Braeburn	3¼ mi. E.	Miscellaneous	Upland	1,275	90–120	6
410	Leechburg	½ mi. W.	Miscellaneous	Hillside	1,000–1,100	90–125	6
411[b]	Vandergrift	4½ mi. SW.	----------	Hillside	1,180	0	----------
412	Vandergrift	3¼ mi. SW.	R. M. Watson	Valley	1,025	72	6
1079	----------	----------	Leechburg Gas well	Valley	750±	1,250	----------
			William Metcalf	----------	----------	----------	----------
	Arnold Borough						
21[a]	Arnold	0	United States Aluminum Co.	Stream plain	860	85	18
	Cook Township						
503[a]	Stahlstown	½ mi. NW.	Frank Hood	Ridge crest	1,780	66	4¼
504	Stahlstown	2 mi. S.	John Carns	Hillside	1,775	102	4¼

[a] Analysis of water by U. S. Geological Survey.
[b] Flowing well or spring.

Chief aquifer			Depth to which well is cased	Water level above (+) or below (—) surface	Method of lift	Capacity of pump	Rate of inflow	Use of water	Remarks
Depth below surface	Character of material	Geologic horizon							
Feet			Feet	Feet		Gallons per minute	Gallons per minute		
175±	Limestone	Clarksburg limestone	85		None		Very small	None	
Near bottom	Sandstone	Clarion sandstone			None			None	Salt water. Located at Garver's Ferry.
40	Top of sandstone	Mahoning sandstone		-3	Gas engine, centrifugal pump	250±	See note	Swimming pool	Two 6-inch wells drilled in bottom of pit 15 feet square and 28 feet deep. Drawdown 22 feet.
Near bottom	Shale	"Pittsburgh Reds"					0-3+	Domestic	Deronda or Shearersburg community.
Near bottom		Top of Mahoning sandstone±					0-3+	Domestic	Ground water erratic due to mine "breaks." Located at Hillvale.
	Jointed sandstone	Morgantown sandstone			Natural flow		1-3	Domestic, stock	Spring, west edge Markle community.
Near bottom	Sandy shale	Mahoning sandstone(?)		-35	Manual, force pump	1-3	Ample	Domestic, stock	
72	Limestone	Vanport limestone			None			None	
443	Sandstone	Burgoon sandstone					Little		Salt water.
798	Sandstone	Squaw sand±							Salt water.
75	Sandstone	Saltsburg sandstone			None			None	
686	Sandstone	Homewood sandstone							Salt water.
75	Gravel	Alluvium	To bottom	-40±	Deep well turbine	600	520	Cooling	Specific capacity approximately 15 g. p. m. for each foot of drawdown.
51	Shale	Bakerstown coal±	16	-31	Manual, force pump	1-3	5	Domestic, stock	
102	Base of sandstone	Freeport sandstone	12	-16	Manual, force pump	1-3	3+	Stock	

No. on Fig. 40	Location: Nearest P. O.	Location: Distance and direction from P. O.	Owner or name	Topographic situation	Altitude above sea level	Depth of well	Diameter of well
					Feet	Feet	Inches
	Derry Township and Borough						
436	New Alexandria	2 mi. NE.	Rushwood Grove	Upland	1,205	70	6¼
437	Blairsville	4¼ mi. W.	Sundial Service Station	Hillside	1,075	90	6¼
438[a]	Blairsville	2½ mi. W.	Liberty Bell Inn	Terrace	1,125	70	6¼
439	Blairsville	⅓ mi. N.	Charles Wainwright	Hillside	1,125	100	6¼
440[b]	Derry	2½ mi. NE.	Ridgeview Park	Hillside	1,450	116	6¼
441[b]	Derry	½ mi. NW.	Westmoreland Water Co.	Valley	1,165±	0	----------
442[a] [b]	Derry	¼ mi. E.	American Window Glass Co.	Valley	1,240	450	8
	Donegal Township and Borough						
505	Donegal	0	Sherman Hauger	Hilltop	1,840	81	4¼
506	Donegal	1½ mi. SE.	Daniel Neiderhiser heirs	Hilltop	1,775	40	4¼
507	Stahlstown	2 mi. S.	George Geary	Hillside	1,725±	82	4¼
508	Jones Mills	1¼ mi. NE.	Peter Ulery	Hillside	1,585	43	4¼
509[a]	Jones Mills	½ mi. SW.	Mrs. Jessie Friedline	Valley	1,505	43	4¼

Chief aquifer			Depth to which well is cased	Water level above (+) or below (—) surface	Method of lift	Capacity of pump	Rate of inflow	Use of water	Remarks
Depth below surface	Character of material	Geologic horizon							
Feet			Feet	Feet		Gallons per minute	Gallons per minute		
50	**Dark shale**	Connellsville sandstone±	20±		Manual, force pump	1-3	3-5	Domestic	
80	Shale	Bakerstown coal±			Manual, force pump	1-3	5-6	Household, high-service station	
60±	Dark shale	Cambridge limestone	20±		Automatic electric, suction pump	2 (?)	20±	Domestic, highway inn, and service station	
70	Coarse sandstone	Morgantown sandstone		-60	Manual, force pump	1-3	3±	Domestic	Located in Indiana County.
114	Base of sandstone	Freeport sandstone ±	19	+3	Natural flow		3±	Domestic supply	
0		Ames limestone ±			Natural flow		25	Municipal supply	Ethel Springs.
175±		Worthington sandstone		+12	Electric, centrifugal pump	500	See note	Sand washing plant	Natural flow 150± gallons a minute.
	Near base (?)	Pottsville formation (?)							
80	Sandstone lentil	Mahoning sandstone (?)	5	—40±	Manual, force pump	1-3	Ample	Household garage	
37	Sandstone	Saltsburg sandstone ±	8	—18	Manual, force pump	1-3	Ample	Domestic, stock	
80	Sandstone lentil	Mahoning sandstone±	20	—20	Manual, force pump	1-3	6	Domestic, stock	
42	Base of sandstone	Worthington sandstone ±	27	—12	Manual, force pump	1-3	Ample	Drinking	Iron-bearing water.
40	Shale	Mahoning sandstone (?)	11	—20	Electric, suction pump		Ample	Domestic, stock	

No. on Fig. 40	Location: Nearest P. O.	Location: Distance and direction from P. O.	Owner or name	Topographic situation	Altitude above sea level	Depth of well	Diameter of well
					Feet	Feet	Inches
	Export Borough						
424[a]	Export	0	Tony Santucci	Valley	1,000	195	$5\frac{5}{8}$
425	Export	0	Nick Secizzel	Valley	1,000	140	$5\frac{5}{8}$
	Fairfield Township						
444	New Florence	$3\frac{1}{2}$ mi. SW.	West Fairfield School	Hilltop	1,430	100±	----------
445[a b]	New Florence	$4\frac{1}{2}$ mi. SW.	R. A. Ross	Valley	1,135	4,610	12
446	Fort Palmer	0	Westmoreland-Connellsville Coal and Coke Co.	Upland	1,375	311	8
	Franklin Township						
420	Murrysville	$2\frac{3}{4}$ mi. N.	William Kane	Hillside	1,260	150	$5\frac{5}{8}$
421	Mamont	$2\frac{1}{4}$ mi. W.	Samuel Greenawalt	Stream head	1,275	67	$5\frac{5}{8}$
422[a]	Murrysville	0	Murrysville School	Valley	910	74	$5\frac{5}{8}$
423[b]	Export	2 mi. N.	James Haymaker	Valley	940±	400±	----------
426	Export	$1\frac{1}{4}$ mi. E.	John Cappa	Hillside	1,050	120	$5\frac{5}{8}$

Chief aquifer			Depth to which well is cased	Water level above (+) or below (—) surface	Method of lift	Capacity of pump	Rate of inflow	Use of water	Remarks
Depth below surface	Character of material	Geologic horizon							
Feet			Feet	Feet		Gallons per minute	Gallons per minute		
192	Sandy black shale	Duquesne coal ±	48	—80	Force pump	3	5+	Household barber shop	
115	Coarse white sandstone	Morgantown sandstone	40	—35±	Manual, force pump	1-3	5+	Household	Not plotted on Fig. 40; near No. 424. Supplies 10 to 12 families.
		Morgantown sandstone (?)			Manual, force pump	1-3	Ample	Domestic	
31	Sandstone lentil (?)	Below Ames limestone							Peoples Natural Gas Co. No. 1339.
159	Sandstone (?)	Saltsburg sandstone ±							
435	Sandstone	Butler sandstone							Well flowed at surface.
940	Sandstone	Burgoon sandstone					Little		
1,200	Sandstone	Burgoon sandstone		+20	Natural flow		30±	Stock	
1,800	Sandstone	Murrysville sand					¼±		
250	Sandstone	Morgantown sandstone	25	—80	Steam, force pump		56	Domestic, boiler feed	Fort Palmer mine. Two other wells to the same horizon have approximate yields of 5 and 25 g. p. m.
Near bottom	White sandstone	Morgantown sandstone	20	—80	Gasoline, force pump	2±	2+	Domestic, stock	
Near bottom		Buffalo sandstone (?)	30±	—50	Manual, force pump	1-3	1—	Domestic	
	Friable sandstone	Mahoning sandstone	42	—20	Automatic electric, force pump	12	12+	Drinking	
		Kittanning sandstone (?)			Natural flow			None	Test hole for coal flows by artesian pressure. Located ¾ mile southeast of Newlonsburg.
Near bottom	Red shale	Lower Pittsburgh limestone ±	4	—60	Manual, force pump	1-3	5+	Domestic	

No. on Fig.	Location: Nearest P. O.	Location: Distance and direction from P. O.	Owner or name	Topographic situation	Altitude above sea level	Depth of well	Diameter of well
					Feet	Feet	Inches
	Franklin Township—Continued						
1064	Murrysville	1¼ mi. N.	Susan Irwin	Valley	940	2,120	------------
			Mrs. Karns	------------	1,050	3,150	------------
			Levi Beamer, No. 1	------------	1,160	3,163	------------
			Tallant heirs, No. 2	------------	1,225	3,269	------------
	Hempfield Township						
457	Jeanette	3¼ mi. SE.	Marshall McIlvain	Valley	1,190	56	5⅝
458	Jeanette	2½ mi. E.	W. Ray Bender	Upland	1,300±	68	5⅝
459	Penn	¼ mi. SE.	Frank Laudadio	Hillside	1,000	105	5⅝
461	Adamsburg	¾ mi. S.	Walter Gongara	Hillside	1,100	119	5⅝
462	Jeanette	1½ mi. SE.	Kemmerer & Mayer	Hillside	1,375	82	5⅝
463	Greensburg	½ mi. NW.	Hofstoff	Hillside	1,100±	100	5⅝
464	Greensburg	2½ mi. E.	Hillview School	Hillside	1,125	89	5⅝
465[b]	Greensburg	3 mi. E.	Curtis Gregg	Valley	1,060	32	5⅝
466	Arona	½ mi. N.	Mike Kottar	Hillside	1,050±	75	5⅝
467	Hunkers	½ mi. E.	Frank E. Geistle	Hillside	980	57	5⅝
1066	Arona	1¼ mi. NE.	C. N. Buzzard, No. 2	Valley	1,000±	3,013	------------

Chief aquifer			Depth to which well is cased	Water level above (+) or below (–) surface	Method of lift	Capacity of pump	Rate of inflow	Use of water	Remarks
Depth below surface	Character of material	Geologic horizon							
Feet			Feet	Feet		Gallons per minute	Gallons per minute		
1,470	Sandstone	Murrysville sand			None			None	
1,633	Sandstone	Murrysville sand			None			None	
1,830	Sandstone	Hundred-foot sand							
65		Buffalo sandstone (?)			None			None	Salt water in Burgoon sandstone at depth 1,025 feet in well No. 2.
260	Sandstone	Freeport sandstone							
545	Sandstone	Homewood sandstone					Much		
145		Ames limestone ±			None			None	
695	Coal	Lower Kittanning coal							
1,824	Sandstone	Murrysville sand							
50	Sandstone	Mahoning sandstone (?)	14	-30	Electric, force pump	3±	15	Domestic	
40	Sandstone	Saltsburg sandstone	12	-30	Manual, force pump	1-3	1/3	Domestic	
65	Sandy shale	Duquesne coal ±	9	-55	Manual, force pump	1-3	10+	Domestic	
Near bottom	Sandstone	Morgantown sandstone	12	-40	Manual, force pump	1-3	Ample	Domestic	
	Red shale	Bakerstown coal ±	12	-28	Automatic electric, force pump	7½	7½+	Highway garage	Grapeville village
Near bottom	Limestone (?)	Fishpot limestone	23	-40	Automatic electric, force pump		10+	House-hold, grounds	
70	Shale	Saltsburg sandstone ±	11	-20	Manual, force pump	1-3	Ample	Drinking	
28	Crevice	Mahoning sandstone	11	+1	Automatic electric, suction pump	3	3+	Household	
Near bottom	Red shale	Clarksburg limestone ±			Manual, force pump	1-3	Ample	Domestic	
50±	Sandstone	Butler sandstone	16	—20	Manual, force pump	1-3	10+	Domestic	
1,830	Sandstone	Nineveh sand			None			None	Peoples Natural Gas Co. No. 1228

No. on Fig. 40	Location: Nearest P. O.	Location: Distance and direction from P. O.	Owner or name	Topographic situation	Altitude above sea level	Depth of well	Diameter of well
					Feet	Feet	Inches
	Hempfield Township—Continued						
1067	Arona	1¾ mi. NE.	J. Eizaman	Upland	1,275	3,777	10–6⅝
1068	Greensburg	2½ mi. E.	Edward Eicher & Co.	Valley	1,125	3,759	10–6⅝
1069	Madison	½ mi. E.	Thomas Brown	Stream head	1,125	3,408	10–6⅝
1070	Madison	1¼ mi. E.	J. F. Logan	Hillside	1,175	3,128	10–5–3/16
1071	New Stanton	1¾ mi. N.	Henry Strouble	Valley	1,080	3,570	10–6⅝
1072	Youngwood	½ mi. SE.	Dr. McMurry	Valley	975	3,149	13–4
	Jeanette Borough						
430[a]	Jeanette	0	Pennsylvania Rubber Co.	Valley	995	280	12
[a]	----------	----------	Pennsylvania Rubber Co., No. 6	Valley	1,000±	404	----------

Chief aquifer			Depth to which well is cased	Water level above (+) or below (—) surface	Method of lift	Capacity of pump	Rate of inflow	Use of water	Remarks
Depth below surface	Character of material	Geologic horizon							
Feet									
1,700	Soft sandstone	Murrysville sand			None			None	Peoples Natural Gas Co. No. 1532
3,044	Sandstone	Speechley sand							
725	Sandstone	Connoquenessing sandstone (?)			None			None	Peoples Natural Gas Co. No. 1750. Not plotted on Fig. 40; near No. 464. Fresh water.
1,740	Sandstone	Hundred-foot sand							Salt water. "Top water" shut off made below Freeport sandstone.
440		Saltsburg sandstone			None			None	Peoples Natural Gas Co. No. 1629. Fresh water.
869	Coal	Mercer coal (?)			None			None	Peoples Natural Gas Co. No. 1785.
998	Sandstone and shale	Mauch Chunk formation							
1,130	Sandstone	Burgoon sandstone							
1,318	Sandstone	Burgoon sandstone							
1,020	Sandstone	Burgoon sandstone			None			None	Peoples Natural Gas Co. No. 1259. Salt water.
1,470	Sandstone	Murrysville sand							Salt water.
2,130	Sandstone	Fifth sand		+	Natural flow				Reported "fresh" water flowing by artesian pressure.
50	Limestone	Upper Freeport limestone			None			None	Peoples Natural Gas Co. No. 1877.
130	Sandstone	Worthington sandstone							
366	Sandstone	Homewood sandstone							
Near bottom	Sandstone	Clarion sandstone		—60	Air lift	100-300	300±	Cooling	Specific capacity about 3½ g. p. m. per foot drawdown.
375±	Friable sandstone	Homewood sandstone					"Large"		Well No. 7, 462 feet deep, encountered but little water.

No. on Fig. 40	Location: Nearest P. O.	Location: Distance and direction from P. O.	Owner or name	Topographic situation	Altitude above sea level	Depth of well	Diameter of well
					Feet	Feet	Inches
	Latrobe Borough						
443	Latrobe	0	Railway Steel Spring Co.	Valley	1,005	630	12–9⅝
	Ligonier Township and Borough						
23	Ligonier	4 mi. E.	Miscellaneous	Valley	1,295	12–15	3–6 feet
473[b]	Ligonier	5 mi. E.	Kissel Springs	Valley	1,460	0	----------
474	Ligonier	2½ mi. SW.	Ligonier Country Club	Ridge crest	1,490±	180	6¼
1076	McCance	½ mi. NW.	Booth & Flinn	Hillside	1,100±	6,822	13–6⅝
	Lower Burrell Township						
413	New Kensington	2 mi. NE.	Miscellaneous	Terrace	1,025–1,050	70±	6
414	Braeburn	2 mi. S.	Miscellaneous	Terrace	965	55–120	----------
415[a]	Braeburn	1¾ mi. SE.	Hillcrest Country Club	Hillside	1,010	140	8
416	New Kensington	2 mi. E.	Black	Hilltop	1,230	150	6¼

Chief aquifer			Depth to which well is cased	Water level above (+) or below (—) surface	Method of lift	Capacity of pump	Rate of inflow	Use of water	Remarks
Depth below surface	Character of material	Geologic horizon							
Feet			Feet	Feet		Gallons per minute	Gallons per minute		
592	Sandstone	Buffalo sandstone	165	--------	--------	--------	Large	Boiler feed	Very little water found above Pittsburgh coal.
--------	Sand and gravel	Surficial rock waste	--------	—8 to 10	Manual, suction pumps	1-3	Ample	Domestic	Village of Waterford. Dug wells. Some are inadequate in dry years.
--------	Sandstone	Butler or Freeport sandstone	--------	--------	Natural flow	--------	3—	None	Former resort.
125±	Shale	Top of Mahoning sandstone±	20	—80	Gasoline, force pump	35	20+	--------	--------
60	Limestone(?)	Murrysville sand±	--------	--------	None	--------	100+	--------	Peoples Natural Gas Co. No. 1588. Well No. 1842, located 590 feet east of No. 1588, is 7,776 feet deep; water entered the lower part of the hole, but probably by leakage around casing.
530	Limestone(?)	Upper part of Catskill formation	--------	--------	--------	--------	5+	--------	
40-50	Sandstone	Mahoning sandstone	20	—40±	Manual and electric, force pumps	1-3	½-10	Household	Leslie plan of lots.
Near bottom	Shale	Brush Creek coal±	--------	—20±	Manual, force pumps	1-3	Ample	Household	Homer Kunkle and J. Smith, contractors. A few deep wells reach the Mahoning sandstone.
95 and 130	Shale	Mahoning sandstone±	30-40	—45	Gasoline, force pump	10	10+	Household	--------
Near bottom	Shale	Brush Creek or Mahoning coal(?)	--------	--------	Manual, force pump	1-3	Very small	Domestic	Near by well 180 feet deep gave barely enough water for drilling.

No. on Fig. 40	Location: Nearest P. O.	Location: Distance and direction from P. O.	Owner or name	Topographic situation	Altitude above sea level	Depth of well	Diameter of well
					Feet	Feet	Inches
	Mount Pleasant Township and Borough						
490	United	$\frac{3}{4}$ mi. NW.	Harry Fisher	Hilltop	1,140	50	$6\frac{1}{4}$
491	Lycippus	1 mi. SE.	Rodman School	Hillside	1,360	67	$4\frac{1}{4}$
492	Mount Pleasant	$2\frac{3}{4}$ mi. N.	Reuben Hissem	Hillside	1,075	293	$4\frac{1}{4}$
493[b]	Mount Pleasant	$2\frac{1}{2}$ mi. NE.	E. E. Goughenowl	Stream head	1,110	0	------------
494	Mammoth	$1\frac{1}{2}$ mi. SW.	Newell	Upland	1,210	100±	$5\frac{5}{8}$
495	Mammoth	$\frac{1}{2}$ mi. S.	Ridgeview School	Hillside	1,290	48	$4\frac{1}{4}$
496[a, b]	Mammoth	$1\frac{1}{4}$ mi. S.	William G. Keck and Sons	Valley	1,190	65±	$4\frac{1}{4}$
497[a, b]	Mammoth	$1\frac{1}{4}$ mi. S.	William G. Keck and Sons	Valley	1,200	104	10
498[a, b]	Mammoth	$1\frac{1}{4}$ mi. S.	William G. Keck and Sons	Valley	1,200	242	$6\frac{5}{8}$
499	Mount Pleasant	$\frac{3}{4}$ mi. NE.	H. C. Frick Coal and Coke Co.	Valley	1,100±	------------	20
500	Mount Pleasant	0	Rice Bros.	Valley	1,070	340	$5\frac{5}{8}$
501	Mount Pleasant	$3\frac{1}{2}$ mi. E.	Thomas Hoch	Valley	1,190	45±	$5\frac{5}{8}$
502	Donegal	$3\frac{1}{4}$ mi. NW.	Harry Albert	Hillside	1,900±	30	$4\frac{1}{4}$
	New Alexandria Borough						
435	New Alexandria	0	Ed Shefler	Terrace	1,020	38	$5\frac{5}{8}$

Chief aquifer			Depth to which well is cased	Water level above (+) or below (—) surface	Method of lift	Capacity of pump	Rate of inflow	Use of water	Remarks
Depth below surface	Character of material	Geologic horizon							
Feet			Feet	Feet		Gallons per minute	Gallons per minute		
Near bottom	Limestone	Uniontown limestone	20±	—25	Manual, force pump	1-3	½	Domestic	----------
67	Dark shale	Lower Freeport coal±	11½	—23	Manual, force pump	1-3	5+	Drinking	----------
290	Sandstone	Morgantown sandstone	98	—111	Manual, force pump	1-3	4+	Domestic, stock	Specific capacity about 0.15 g. p. m. per foot of drawdown.
0	Sandy shale	Uniontown sandstone±	----------	----------	Natural flow	----------	5	Domestic, service station	Spring.
Near bottom	----------	Uniontown limestone±	20±	—10±	Manual and gasoline, force pump	1-5	5+	Domestic, stock	----------
48	Base of sandstone	Morgantown sandstone	20	—12	Manual, force pump	1-3	Ample	Drinking	----------
Near bottom	----------	Saltsburg sandstone	18	+5	Electric, suction pump	40	40+	Cooling water	Natural flow 5 g. p. m. Specific capacity about 2 g. p. m. per foot drawdown.
100±	----------	Saltsburg sandstone	20±	+14	Natural flow	----------	15+	Bottling	Maximum use about 5,000 gallons a day.
Near bottom	----------	Mahoning sandstone(?)	121	+18	Natural flow	----------	25+	Bottling reserve	Nos. 497 and 498 not plotted on Fig. 40; they are one well in which two aquifers are developed separately.
40	Limestone	Uniontown limestone	----------	—4	Bailer	----------	15±	None	Power conduit being drilled (October, 1926) at Standard Mine.
----------	----------	Morgantown sandstone(?)	140	----------	Force pump	----------	----------	Drinking, shop use	Glass factory, maximum use perhaps 1,000 gallons a day.
40	Sandy shale	Top of Vanport limestone	30±	—10	Manual, force pump	1-3	Ample	Domestic	Village of Laurelville.
29	Crevice	Butler sandstone±	----------	—23	Manual, force pump	1-3	5+	Domestic, stock	Village of Rodney.
Near bottom	Shale	Above Morgantown sandstone	20±	—10	Manual, force pump	1-3	1¼	Domestic	----------

No. on Fig. 40	Location: Nearest P. O.	Location: Distance and direction from P. O.	Owner or name	Topographic situation	Altitude above sea level	Depth of well	Diameter of well
					Feet	Feet	Inches
	New Salem Borough						
433[a]	Delmont	0	Paul Jobe	Stream head	1,250	45–75	5⅝
	North Huntington Township						
447	Ardara	0	Roger McCall and others	Hillside	950±	155–185	5⅝
448	Irwin	1½ mi. W.	Studebaker Garage	Hillside	1,200	200	5⅝
449	Adamsburg	1 mi. NW.	Julius Diebold	Hillside	1,100	59	5⅝
1065	Trafford	0	Westinghouse Foundry Co., No. 1	Valley	775±	1,960	----------
			J. F. Beighley	----------	950	2,315	----------
			M. J. Montgomery heirs, No. 1	----------	800±	2,259	----------
			Duff heirs, No. 2	----------	840	2,325	----------
			Mary G. Stewart	----------	800±	2,275	----------
	Parnassus Borough						
22	Parnassus	0	National Lead and Oil Co. of Pennsylvania	Stream plain	860	55	120

Chief aquifer			Depth to which well is cased	Water level above (+) or below (—) surface	Method of lift	Capacity of pump	Rate of inflow	Use of water	Remarks
Depth below surface	Character of material	Geologic horizon							
Feet			Feet	Feet		Gallons per minute	Gallons per minute		
35	Base of limestone	Lower Pittsburgh limestone		—10	Manual, suction and force pumps	1-3	5+	Domestic	
Near bottom		Saltsburg sandstone(?)	20±	100±	Manual, force pumps	1-3	Ample	Domestic	
160	Limestone	Fishpot limestone	20	—160	Manual, force pump	1-3	Very small	Highway garage	Located at Jacktown village.
Near bottom	Limestone	Uniontown limestone	12	—25	Manual, force pump	1-3	½±	Domestic	
1,460	Sandstone	Murrysville sand			None		Large	None	
1,630	Sandstone	Hundred-foot sand					Very small		
75	Sandstone	Saltsburg sandstone			None			None	
620	Sandstone	Homewood sandstone							
680	Sandstone	Connoquenessing sandstone					Large		"Hole full of water."
70	Top of limestone	Brush Creek limestone (?)			None			None	
225	Shale	Upper part of Allegheny formation							
1,484	Sandstone	Murrysville sand					Large		
745	Sandstone	Homewood sandstone			None		3±	None	
1,230	Sandstone	Burgoon sandstone					1½±		
1,530	Sandstone	Murrysville sand					10±		
305	Shale	Below Up. Kittan. coal			None			None	Salt water.
Near bottom	Gravel	Alluvium	To bottom	—32	Steam, suction pump	250	200	Industrial	Brick and cement masonry with inlet ports in bottom course of brick; specific capacity about 10 g. p. m. per foot of drawdown.

No. on Fig. 40	Location		Owner or name	Topographic situation	Altitude above sea level	Depth of well	Diameter of well
	Nearest P. O.	Distance and direction from P. O.					
					Feet	Feet	Inches
	Penn Township						
427	Trafford	$1\frac{3}{4}$ mi. E.	Oliver Graham	Stream head	1,050±	77	$5\frac{5}{8}$
			C. W. Crew	Stream head	1,050±	250	$5\frac{5}{8}$
428	Harrison City	0	H. Albert Lauffer	Valley	1,000	41	$5\frac{5}{8}$
429	Claridge	0	Westmoreland Coal Co.	Valley	1,040	100±	$5\frac{5}{8}$
			Harvie Pedder, No. 2	----------	915	2,275+	----------
			E. Dam heirs, No. 1	----------	1,070	2,377	----------
			E. Dam heirs, No. 2	----------	----------	2,400	----------
	Rostraver Township						
475	West Newton	$2\frac{3}{4}$ mi. SW.	Frank Stoneman	Hilltop	1,175	40	$5\frac{5}{8}$
476	West Newton	$\frac{3}{4}$ mi. W.	Shaeffer	Hillside	900±	120	$5\frac{5}{8}$
477	North Bellevernon	$1\frac{3}{4}$ mi. NE.	Elias Browneller	Terrace	1,050	237	$5\frac{5}{8}$
478	North Bellevernon	$1\frac{1}{2}$ mi. E.	Robert Allen	Terrace	925	150+	$5\frac{5}{8}$
479[a]	North Bellevernon	$\frac{3}{4}$ mi. E.	G. H. Clark	Stream head	940	60	$5\frac{5}{8}$

Chief aquifer: Depth below surface	Chief aquifer: Character of material	Chief aquifer: Geologic horizon	Depth to which well is cased	Water level above (+) or below (—) surface	Method of lift	Capacity of pump	Rate of inflow	Use of water	Remarks
Feet			Feet	Feet		Gallons per minute	Gallons per minute		
35	Sandstone	Saltsburg sandstone	------	—17	Automatic electric, suction pump	2	Ample	Domestic	Level Green community.
Near bottom	Red shale	"Pittsburgh Reds"	------	------	------	------	1/10	------	Level Green community. Near by well 80 feet deep finds ample domestic supply in Saltsburg sandstone.
30±	Limestone	Benwood limestone	9	—20	Manual, force pump	1-3	Ample	Domestic	------
85±	Limestone	Clarksburg limestone	20	-50	Manual, force pump	1-3	3+	Domestic	Each well ample for 5 or 6 miners' dwellings.
1,200	Sandstone	Burgoon sandstone	------	------	None	------	------	None	Philadelphia Gas Co. No. 2071.
1,675	Sandstone	Murrysville sand	------	------	None	------	------	None	Carnegie Natural Gas Co. No. 156.
150	------	Saltsburg sandstone ±	------	------	None	------	------	None	Carnegie Natural Gas Co. No. 240.
500	Coal	Middle Kittanning coal	------	------	------	------	2±	------	------
Near bottom	Limestone	Waynesburg limestone	------	-30	Manual, force pump	1-3	5+	Domestic, stock	------
118	Sandstone	Pittsburgh sandstone	65	-86	Manual, force pump	1-3	1±	Domestic	------
230	Coal	Little Pittsburgh coal	20±	-105	Manual, force pump	1-3	Ample	Domestic	------
149	Sandstone	Connellsville sandstone	25	-30	Manual, force pump	1-3	5+	Domestic	------
Near bottom	Limestone	Redstone limestone	------	-20±	Manual, force pump	1-3	Ample	Domestic	------

No. on Fig. 40	Location: Nearest P. O.	Location: Distance and direction from P. O.	Owner or name	Topographic situation	Altitude above sea level	Depth of well	Diameter of well
					Feet	Feet	Inches
	Salem Township						
431[a]	Slickville	0	Bethlehem Mines Corp.	Valley	1,020	225	8
432	Delmont	1¾ mi. N.	Astorri Garage	Valley	1,120	38	5⅝
434	New Alexandria	3¼ mi. W.	Ed. Lyons	Hillside	1,050	90	5⅝
			P. R. Gwyn	----------	----------	2,310	----------
	Scottdale Borough						
489[a]	Scottdale	0	Scottdale Ice and Coal Co.	Valley	1,020	150	8
	Sewickley Township						
450	Scott Haven	0	Pittsburgh Coal Co.	Valley	860	99–103	5⅝
451	Rillton	0	Keystone Planing Co.	Valley	1,000	100±	5⅝
452	Herminie	0	Ocean Coal Co.	Hillside	925±	103	5⅝
453	Herminie	½ mi. NE.	Keystone Coal Co.	Valley	900	255	5⅝
455	West Newton	2¾ mi. NE.	George Brewno	Ridge crest	1,040	84	5⅝
456	Madison	1¼ mi. SW.	Whyle Coal Co.	Valley	980	150	5⅝
			Gaut and Byerly heirs, No. 1	----------	1,120	----------	----------
			Jeanette Land Co.	----------	1,110	4,370	----------

Chief aquifer			Depth to which well is cased	Water level above (+) or below (—) surface	Method of lift	Capacity of pump	Rate of inflow	Use of water	Remarks
Depth below surface	Character of material	Geologic horizon							
Feet			Feet	Feet		Gallons per minute	Gallons per minute		
220±	Sandstone	Buffalo sandstone(?)	105	-85±	Electric, force pump	40	----------	Domestic supply	----------
32	Limestone	Pittsburgh limestone	12	-7	Automatic electric, suction pump	----------	Ample	Domestic, garage	----------
----------	----------	Morgantown sandstone (?)	20±	-50	Manual, force pump	1-3	Ample	Domestic	----------
970	Sandstone	Burgoon sandstone (?)	----------	----------	None	----------	----------	None	----------
100±	Sandstone	Morgantown sandstone	30	-30	Steam, force pump	140	140+	Boiler feed	Specific capacity about 10 g. p. m. per foot drawdown.
70-95	Shale	Pittsburgh sandstone ±	60	-50	Manual, force pump	1-3	3±	Domestic	----------
----------	Limestone	Uniontown limestone	5-6	-12±	Steam, suction pump	----------	3½	Boiler feed	----------
100	Limestone	Benwood limestone	----------	-90±	Manual, force pump	1-3	Ample	House-hold	----------
249	Hard sandstone	Morgantown sandstone	----------	-15	Electric, force pump	35 (?)	----------	Boiler feed, domestic	Well near mule stable.
Near bottom	Sandstone	Uniontown sandstone	5	-25	Manual, force pump	1-3	5+	Domestic	Tourist camping park supply.
Near bottom	Sandstone	Morgantown sandstone	----------	-45±	Electric, force pump	----------	10+	----------	----------
1,456	Sandstone	Pottsville formation	----------	----------	None	----------	----------	None	Salt water.
2,268	Sandstone	Murrysville sand	----------	----------	None	----------	----------	None	Peoples Natural Gas Co. No. 1270.

No. on Fig. 40	Location		Owner or name	Topographic situation	Altitude above sea level	Depth of well	Diameter of well
	Nearest P. O.	Distance and direction from P. O.					
					Feet	Feet	Inches
	South Huntingdon Township						
481	Wyano	2 mi. W.	Hunter	Hilltop	1,160	75	5⅝
482	Wyano	¼ mi. N.	Walter Robinson	Ridge crest	975	112	5⅝
483	Wyano	1½ mi. NE.	Martin Penrock	Hilltop	1,0[illegible]±	188	5⅝
484	Hunkers	1¼ mi. SW.	Samuel Morton	Upland	1,200	68	5⅝
485	West Newton	2 mi. S.	American Reduction Co., No. 4	Valley	775±	176	8
486	Smithton	2 mi. N.	Joe Williams	Terrace	935	79	5⅝
487	Wyano	1 mi. S.	John Nagy	Creek head	1,160	119	5⅝
488	Smithton	1½ mi. NW.	Pittsburgh Coal Co.	Valley	775	95	5⅝
	Suterville Borough						
454	Suterville	0	Westmoreland Brewing Co.	Stream plain	870	91	5⅝
	Unity Township						
468	Luxor	¾ mi. S.	Edward Alexander	Hilltop	1,200	80	6¼
469[b]	Latrobe	1¼ mi. NW.	George Seiler	Valley	1,000	42	6¼
470	Luxor	3 mi. S.	Mountain View Hotel	Ridge crest	1,345	120	6¼
471	Luxor	3 mi. S.	Jay Seger	Hillside	1,270	295	8
472[b]	United	1½ mi. N.	O. M. Deibler	Valley	1,010±	60	8

Chief aquifer			Depth to which well is cased	Water level above (+) or below (—) surface	Method of lift	Capacity of pump	Rate of inflow	Use of water	Remarks
Depth below surface	Character of material	Geologic horizon							
Feet			Feet	Feet		Gallons per minute	Gallons per minute		
65	Black shale	Waynesburg "A" coal	20	-20	Manual, force pump	1-3	5+	Domestic	----------
Near bottom	Sandstone	Connellsville sandstone	31	-35	Manual, force pump	1-3	3±	Domestic, boiler feed	----------
----------	Red shale	Clarksburg limestone ±	10	----------	Manual, force pump	1-3	Ample	Domestic	----------
Near bottom	Sandstone	Saltsburg sandstone	7½	-20	Manual, force pump	1-3	5+	Domestic	----------
Near bottom	Sandstone	Connellsville sandstone	50	-40	Air lift	----------	100+	Boiler feed	----------
35±	Black shale	Cassville shale (?)	21	-21	Manual, force pump	1-3	10±	Domestic	----------
Near bottom	Sandstone	Morgantown sandstone ±	20	-60	Manual, force pump	1-3	Ample	Domestic	----------
55	Sandstone	Pittsburgh sandstone	----------	-35	Manual, force pump	1-3	5±	Domestic	Dwellings at Fitzhenry mine.
60±	White sandstone	Connellsville sandstone	----------	----------	Gas engine, force pump	75±	----------	None	Four wells drilled 200 yards upstream to depth 215 feet did not encounter this sandstone.
60	Shale	Above Saltsburg sandstone	20±	-40	Manual, force pump	1-3	1	Domestic	----------
30	Shale	Buffalo sandstone ±	20	+Slight	None	----------	3±	Swimming pool	----------
75	Shale	Buffalo sandstone ±	20	-60	Automatic electric, force pump	----------	2±	Household	----------
250	Shale	Mahoning sandstone ±	20	-90	Manual, force pump	1-3	1±	Household	Not plotted on Fig. 40; located 350 yards southeast of No. 470.
40	Shale	Below Connellsville ss.	8	+Slight	----------	----------	5±	Swimming pool	----------

No. on Fig. 40	Location: Nearest P. O.	Location: Distance and direction from P. O.	Owner or name	Topographic situation	Altitude above sea level	Depth of well	Diameter of well
					Feet	Feet	Inches
	Unity Township—Continued						
1073	Luxor	1¾ mi. SE.	M. A. Saxman	Hillside	1,325	1,455	10–8
1074	Luxor	2 mi. S.	L. B. Huff	Valley	1,175	1,436	10–6⅝
1075	Luxor	2¾ mi. S.	L. B. Huff Estate	Valley	1,250	3,484	10–8¼
	Upper Burrell Township						
417	Renton	3 mi. NE.	Wills School	Valley	975	73	6
1060	Renton	3 mi. N.	W. M. Dinsmore	Hillside	890	----------	----------
1061	Renton	2½ mi. NE.	W. J. Beacomb	Valley	910	1,600+	----------
	Washington Township						
418	Mamont	3½ mi. N.	Samuel Walker	Hillside	1,250	60	5⅝
419	Mamont	0	Paul Irwin	Upland	1,200	90	5⅝
1062	Vandergrift	3 mi. SW.	Calvin Barber, No. 2	Hillside	1,100	----------	----------

Chief aquifer: Depth below surface	Chief aquifer: Character of material	Chief aquifer: Geologic horizon	Depth to which well is cased	Water level above (+) or below (—) surface	Method of lift	Capacity of pump	Rate of inflow	Use of water	Remarks
Feet			Feet	Feet		Gallons per minute	Gallons per minute		
1,362	Sandstone	Murrysville sand	----------	-1,100	Force pump	5	5+	None	Peoples Natural Gas Co. No. 664. Water-supply well 285 feet deep penetrates Worthington sandstone.
735	Sandstone	Burgoon sandstone	----------	----------	None	----------	----------	None	Peoples Natural Gas Co. No. 659.
1,281	Sandstone	Murrysville sand	----------	----------	----------	----------	----------	----------	Water-supply well 150 feet deep penetrates Freeport sandstone.
3,376	Sandstone and shale	Uppermost part of Portage formation	----------	----------	None	----------	----------	None	Peoples Natural Gas Co. No. 1371.
50±	Sandy black shale	Bakerstown coal ±	8	----------	Manual, force pump	1-3	Ample	Drinking	----------
1,224	Sandstone	Burgoon sandstone	----------	----------	None	----------	----------	None	T. W. Phillips Gas & Oil Co.
1,590	Sandstone	Murrysville sand	----------	----------	None	----------	----------	None	T. W. Phillips Gas & Oil Co.
Near bottom	Sandy black shale	Bakerstown coal +	----------	-9	Automatic electric, suction pump	1-3	25+	Swimming pool	----------
Near bottom	Red shale	"Pittsburgh Reds"	48	-60	Automatic electric, force pump	2	Ample	Domestic, stock	----------
605	----------	Pottsville sandstone ±	----------	----------	None	----------	----------	None	T. W. Phillips Gas and Oil Co. Last "top water." Water-supply well 165 feet deep, penetrates Mahoning sandstone.

No. on Fig. 40	Location: Nearest P. O.	Location: Distance and direction from P. O.	Owner or name	Topographic situation	Altitude above sea level	Depth of well	Diameter of well
					Feet	Feet	Inches
	Washington Township—Continued						
1063	Mamont	3½ mi. NW.	Frank Watt, No. 2	Hillside	1,130	2,000+	------------
			Beaver Valley	Valley	1,005	1,301	------------
			George Kistler	------------	1,080	3,935	------------
	West Newton Borough						
480[a]	West Newton	½ mi. S.	West Newton Borough	Valley	770	200	5⅝

[a] Analysis of water by United States Geological Survey.
[b] Flowing well or spring.

Chief aquifer			Depth to which well is cased	Water level above (+) or below (—) surface	Method of lift	Capacity of pump	Rate of inflow	Use of water	Remarks
Depth below surface	Character of material	Geologic horizon							
Feet			Feet	Feet		Gallons per minute	Gallons per minute		
1,745	Sandstone	Murrysville sand	----------	----------	None	----------	----------	None	T. W. Phillips Gas & Oil Co.
326	Sandstone	Homewood sandstone	----------	----------	None	----------	----------	None	Salt water. Located on Beaver Run 2⅓ miles east of village of North Washington.
461	Sandstone and shale	Connoquenessing sandstone	----------	----------	----------	----------	----------	----------	Salt water.
487	Sandstone	Burgoon sandstone	----------	----------	----------	----------	----------	----------	Salt water.
602	Sandstone	Burgoon sandstone	----------	----------	----------	----------	----------	----------	Salt water.
907	Dark shale	Burgoon sandstone	----------	----------	----------	----------	----------	----------	Salt water.
1,240	Sandstone	Murrysville sand	----------	----------	----------	----------	----------	----------	Salt water.
215	Shale	Bakerstown coal ±	----------	----------	None	----------	----------	None	----------
1,650	Sandstone	Murrysville sand	----------	----------	----------	----------	----------	----------	Salt water.
Near bottom	Sandstone	Connellsville sandstone	35	-25	Electric, force pumps	----------	20-25	Munic'pal supply	Twelve wells.

Driller's log of N. Secizzel well at Export

(No. 425, Fig. 40.)

	Thickness (Feet)	Depth (Feet)
Shale	20	0–20
Limestone	5	20–25
Shale, blue-gray	8	25–33
Shale, red	35	33–68
Limestone	6	68–74
Shale, gray	26	74–100
Sandstone (Morgantown), white and friable, water bearing at 115 feet	40	100–140

Log of Pennsylvania Rubber Co.'s well No. 7, at Jeanette

(No. 430, Fig. 40.)

	Thickness (Feet)	Depth (Feet)
Not reported	50	0–50
Allegheny formation:		
Sandstone (Butler), dominant grain size 0.25–0.5 mm. diameter	35	50–85
Shale, carbonaceous at top (Lower Freeport coal?) and variegated below	50	85–135
Sandstone (Freeport), white, fine-grained	15	135–150
Shale, carbonaceous at top (Upper Kittanning coal?)	10	150–160
Sandstone (Worthington), white, quartz grains, dominant size about 1 mm. diameter	10	160–170
Shale, variegated and sandy	80	170–250
Sandstone (Kittanning), white and iron-stained quartz grains 0.1 to 1.0 mm. diameter	45	250–295
Shale, gray	25	295–320
Sandstone (Clarion), light-gray, fine-grained and shaly. Separation from sandstone below is somewhat uncertain	15	320–335
Pottsville formation:		
Sandstone (Homewood), buff at top, white in lower part, grains 0.1 to 1.0 mm. in diameter though usually well assorted in each sample. Small yield of water, though yields copiously in well No. 6	50	335–385
Shale, olive gray	10	385–395
Sandstone (Connoquenessing) light gray, shaly	5	395–400
Shale, dark gray at top	40	400–440
Mauch Chunk formation:		
Shale, red and maroon	22	440–462

Driller's log of Railway Steel Spring Company's well at Latrobe

(No. 443, Fig. 40.)

	Thickness (Feet)	Depth (Feet)
Soil and clay	12	0–12
Shale, light and dark	98	12–110
Sandstone	5	110–115
Shale	35	115–150
Coal (Pittsburgh)	7	150–157
Shale and fireclay	54	157–211
Shale, soft	74	211–285
Sandstone (Connellsville?)	31	285–316
Shale, gray and red	70	316–386
Shale, soft, water at 546 feet	175	386–561
Sandstone (Saltsburg), water at 592 feet	69	561–630

Driller's log of R. A. Ross well near New Florence

(No. 445, Fig. 40.)

	Thickness (Feet)	Depth (Feet)
Soil and rock waste	15	0–15
Conemaugh formation:		
Sandstone, water at base	16	15–31
Shale	17	31–48
"Lime", dark colored	20	48–68
Shale	12	68–80
"Lime", water at base	79	80–159
Sandstone (Buffalo), white	60	159–219
Shale	18	219–237
Sandstone (Mahoning)	63	237–300
"Lime"	50	300–350
Allegheny formation:		
Coal (Upper Freeport)	2	350–352
"Lime"	48	352–400
Sandstone (Butler), water at base, flowed by artesian pressure	35	400–435
Shale, carbonaceous (Lower Freeport coal)	5	435–440
Sandstone (Freeport)	46	440–486
Coal (Upper Kittanning)	8	486–494
"Lime"	25	494–519
Sandstone (Worthington and Kittanning)	100	519–619
Shale	10	619–629
Sandstone (Clarion?) / Pottsville formation: / Sandstone (Homewood)	100	629–729
Shale (Mercer)	10	729–739
Sandstone (Connoquenessing)	61	739–800
"Lime" (lower portion or all may belong to Mauch Chunk formation)	135	800–935
Mauch Chunk formation:		
Shale, red	5	935–940
Pocono formation:		
Sandstone (Burgoon), a little water with gas from 940 to 1,000 feet, principal source of water at 1,200 feet flowed at surface by artesian pressure	360	940–1400
Shale	25	1400–1425
Sandstone	175	1425–1600
"Lime"	40	1600–1640
Sandstone (Murrysville±), 1 gallon water per minute at base	160	1640–1800
Catskill and Chemung formations:		
"Lime"	140	1800–1940
Shale, red	140	1940–2080
Sandstone	20	2080–2100
Shale, red	280	2100–2380
Sandstone	35	2380–2415
"Lime"	415	2415–2830
Sandstone	40	2830–2870
"Lime"	70	2870–2940
Sandstone	50	2940–2990
Shale, red	50	2990–3040
"Lime"	60	3040–3100
Sandstone	30	3100–3130
Shale, red	20	3130–3150
"Lime", white	40	3150–3190
"Lime"	210	3190–3400
"Lime" and sand	8	3400–3408
"Lime"	120±	3408–4610

Note. Peoples Natural Gas Co.'s well No. 1,339. Driller's "lime" is presumably a dense, gritless shale and certainly not limestone. Stratigraphic correlations are tentative only.

Driller's log of Westmoreland-Connellsville Coal and Coke Co.'s well No. 1 at Fort Palmer

(No. 446, Fig. 40.)

	Thickness (Feet)	Depth (Feet)
Soil and rock waste	20	0–20
Shale	8	20–28
Limestone (Lower Pittsburgh)	8	28–36
Fireclay	16	36–52
Shale	45	52–97
Shale, sandy	13	97–110
Shale	21	110–131
Limestone (Clarksburg)	3	131–134
Shale, blue-gray, clayey	41	134–175
Sandstone (Morgantown), water at base	75	175–250
Shale, sandy	20	250–270
Limestone (Ames)	5	270–275
Shale, black (Harlem Coal?)	8	275–283
Shale, blue-gray	20	283–303
Shale, sandy	8	303–311

Driller's log of Reuben Hissem well near Mount Pleasant

(No. 492, Fig. 40.)

	Thickness (Feet)	Depth (Feet)
Soil and rock waste	5	0–5
Shale	1	5–6
Coal (Redstone)	4	6–10
Sandstone, buff and shaly	8	10–18
Shale, buff at top, bluish-gray at bottom	21	18–39
Shale, dark and sandy	27	39–66
Shale, carbonaceous	12	66–78
Coal (Pittsburgh or "Connellsville")	8	78–86
Fireclay, gray	23	86–109
Sandstone, gray	11	109–120
Shale and sandstone, interbedded	9	120–129
Limestone (Lower Pittsburgh)	7	129–136
Shale, variegated	72	136–208
Shale, red	8	208–216
Shale, bluish-gray	16	216–232
Limestone (Clarksburg)	6	232–238
Shale, bluish gray	18	238–256
Shale, red	24	256–280
Shale, greenish gray	10	280–290
Sandstone lentil, water at base	1	290–291
Sandy limestone	2	291–293

Driller's log of George Geary well near Donegal

(No. 507, Fig. 40.)

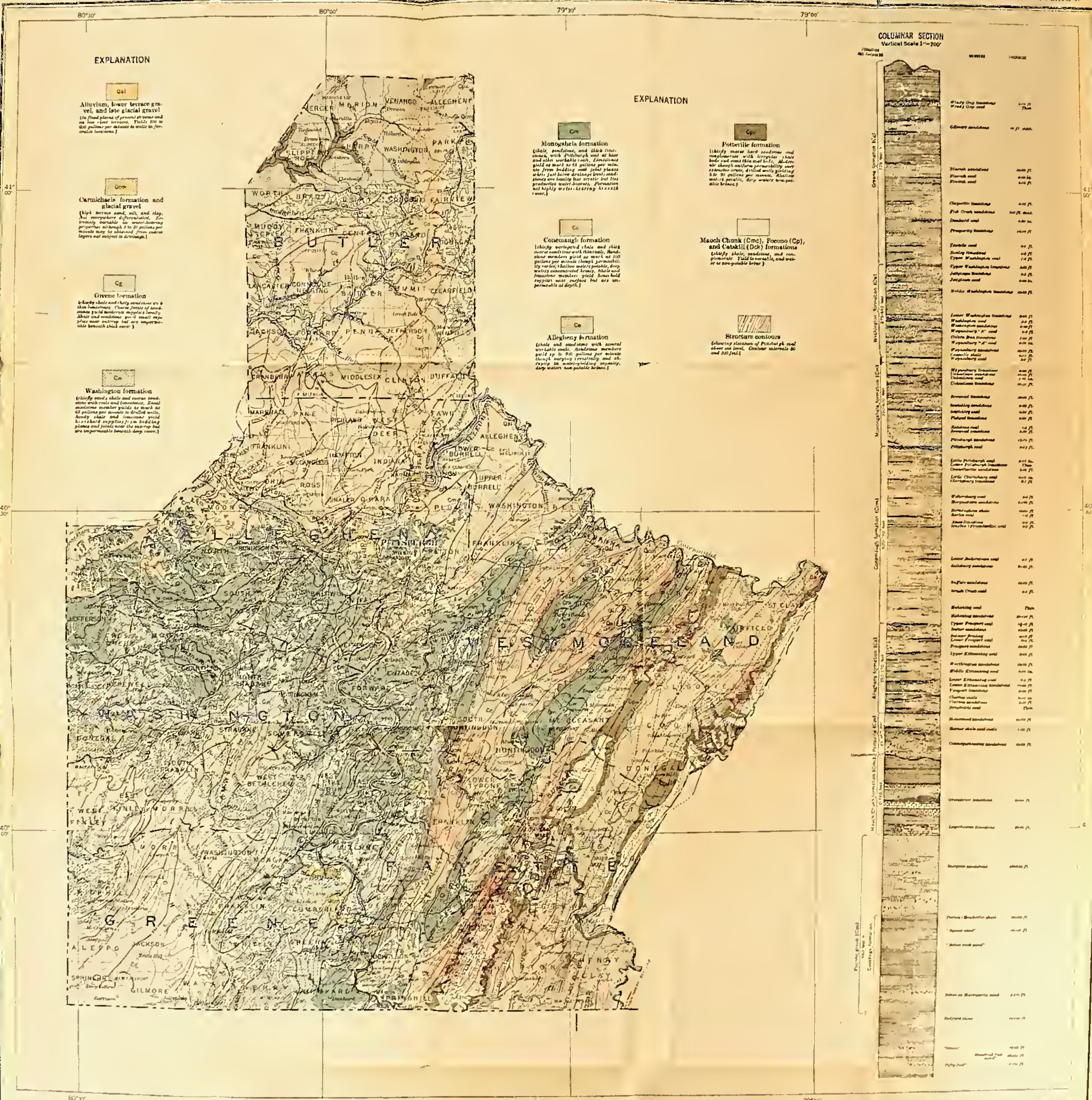
	Thickness (Feet)	Depth (Feet)
Soil and rock waste	8	0– 8
Shale, weathered	10	8–18
Sandstone, buff	4	18–22
Shale, bluish-gray, small yield of water at base	16	22–38
Shale, black	14	38–52
Shale, clayey	20	52–72
Shale, variegated	8	72–80
Sandstone lentil, greenish-gray, water-bearing	2	80–82

INDEX

U. S. GEOLOGICAL SURVEY
W. C. MENDENHALL, DIRECTOR

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF INTERNAL AFFAIRS
TOPOGRAPHIC AND GEOLOGIC SURVEY
GEORGE H. ASHLEY, STATE GEOLOGIST

BULLETIN W-1, PLATE 1.



GEOLOGIC MAP OF SOUTHWESTERN PENNSYLVANIA

Scale 1:380,160

Geology from Geologic Map of Pennsylvania published by Pennsylvania Topographic and Geologic Survey, 1932. Structure contours compiled from published and unpublished folios of geologic atlas of U. S. Geological Survey, and from publications of Pennsylvania Geological Survey.